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TECHNICAL REPORT
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THE DEVELOPMENT OF BUILT-IN MECHANISMS FOR SOFTENING AND REHYDRATING COMPACTED FOOD BARS

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R. A. Lampi

Central Engineering Laboratories
FMC Corporation
Santa Clara, California

Contract No. DA 19-129-AMC-44(N)

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UNITED STATES ARMY
NATICK LABORATORIES
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FOREWORD

In the design of food packets to be carried by the combat soldier during prolonged periods when resupply can not be assured, weight and bulk are major factors subordinate only to acceptability, safety and nutritional value. Dehydration combines a reliable mechanism of protecting food from microbial deterioration with a generally practicable means of minimizing weight. Freeze drying for reasons of product acceptability is the preferred method for dehydrating all animal tissue and many fruits and vegetables; freeze drying, however, produces no significant loss of volume. Earlier investigations have pointed to compression as a feasible means for reducing volume of freeze dried foods and other foods having a porous structure or a low bulk density. Experience has demonstrated that compression of dried foods may yield a structure which is too hard for direct consumption by a soldier. Compressed foods which are excessively hard generally have a poor response to rehydration.

This investigation seeks to develop and demonstrate effective built-in mechanisms which can be used in compressed food bars to avoid excessive hardness and to facilitate sheering by the incisors of bite size pieces which can subsequently be masticated and swallowed without difficulty. It is expected that mechanisms effective against excessive hardness will also accelerate rehydration of compressed bars.

The investigation was performed at the Central Engineering Laboratories of the FMC Corporation, Santa Clara, California. The technical effort was directed by Dr. R. A. Lampi, Official Investigator. He was assisted by R. W. Farrier, H. Takahashi, M. H. Nosrati, S. W. Sierra, and Miss Jean Lennon. The investigation was funded from the project titled, COMBAT FEEDING SYSTEMS, under Contract DA19-129-AMC-44. The Project Officer for U. S. Army Natick Laboratories was Dr. M. C. Brockmann of the Food Laboratory.. Mr. J. M. Tuomy, also of the Food Laboratory, served as Alternate Project Officer.

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ABSTRACT

Compressed bars representing various vegetables and fruits, a cereal, a bakery item, meat, a casserole type item, non fat milk solids, and a high cook caramel candy were prepared in a manner to accentuate hardness. The effectiveness of various mechanisms for improving bitability and mastication were examined. A laminating technique resulting in a bar of thin layers held together with a mild binder was observed to be generally applicable, since individual layers could be separated for easy mastication and accelerated hydration. For fibrous products bitability was markedly improved by application of the compressive force at 90° from the direction of the bite. Physical, chemical and sensory data are recorded for bars stored at four different temperatures.

I. INTRODUCTION

The necessity of reduction of cube and weight in foods that are to be used in military rations has resulted in the development of compacted food bars. However, in the use of these food bars, it has often times been found that the bars are extremely hard and/or difficult to rehydrate.

The effort carried out under Phase I of Quartermaster Corps Contract DA 19-129-AMC-44(N) dealt mainly with exploring the nature of excessive hardness and/or resistance to rehydration in compacted foods and then developing, testing, and recommending a built-in mechanism to relieve these objectionable features.

1. Certain specifications with regards to the built-in mechanisms were laid down in the Statement of Work. Summarized briefly, these were:

    a. Rehydration time - not more than 30 minutes.

    b. Bitability - readily consumed.

    c. Use of FDA approved materials.

    d. No deleterious effects on the flavor, odor, color, caloric and nutritional characteristics of the compacted bars.

2. Observations to be made on the bars with the built-in mechanisms and corresponding control bars after a 3 months storage period at 100°F, 70°F, 40°F and temperature cycling (2 cycles per week, maximum 40°F and minimum 0°F) were also specified:

    a. Functional
    b. Sensory
    c. Microbiological
    d. Physical
    e. Chemical

For Phase II, the research effort was divided into two aspects. One was to compensate for storage deficiencies noted in the built-in mechanism (laminating) developed for two compacted foods in Phase I (freeze dried carrots and strawberries) and develop and apply the laminating mechanism to a compacted casserole (rice-beef-pea), non fat milk solids and dehydrated meat bars. (Laminating involves making thin compact chips - laminates - and sticking them together by compression and/or other means - lamination.)

The other aspect was to identify levels of pressure, humidity and oxygen to be avoided during storage of the five aforementioned compacted foods.

1. Certain specifications with regards to the laminating mechanisms were laid down in the Statement of Work. Summarized briefly, these were:

    a. Rehydration time - not more than 30 minutes.

b. Bitability - bitesize portions separable through normal action of the incisors.

c. Laminating materials limited to not more than 20% either by weight or volume of the fabricated bar and to not less than 4.0 Kg-cal utilizable in human metabolism per gram.

d. Use of FDA approved materials.

e. No material transfer between bar substance and laminating materials.

f. Recommend systems readily adaptable to commercial-type operations.

2. Observations to be made on the laminated and corresponding control foods after a 3 months storage period at 100°F and temperature cycling (2 cycles per week, maximum 40°F and minimum 0°F) were also specified:

   a. Physical
   b. Organoleptic
   c. Chemical
   d. Microbiological

For the storage conditions identified above, the effects of sustained pressure, humidity and gaseous oxygen on the various properties of food bars prepared with the laminated mechanism were to be noted.

II. EXPERIMENTAL

A. Selection and Preparation of Foods

1. Food Samples

Five food groups containing foods representing different types of hardness and/or resistance to rehydration were used during Phase I.

Dehydrated vegetables - freeze dried carrots and onions; air dried cabbage.

Dehydrated fruit - freeze dried strawberries, apples and pineapple, low moisture raisins.

Dry cereal - puffed rice.

Bakery product - cookies.

Confectionery - high cook caramel.

In experiments aimed at relieving the hardness and/or resistance to rehydration of all of these foods, a promising built-in mechanism was developed (lamination). Of these foods, the laminating mechanism was incorporated into compacted, air dried cabbage, cookie, caramel, and freeze dried carrot, strawberry, pineapple and onion bars, and the seven foods were submitted to a storage study.

For Phase II the research effort was concentrated on freeze-dried carrots and strawberries with a casserole, nonfat milk solids and dehydrated meat added.

A list of the foods, type or variety information, condition as purchased, and sources are listed in Table 1.

All of the freeze dried foods were processed in the FMC Pilot Freeze Dryer as follows:

Trays loaded with frozen food were placed in the freeze dryer. The pressure was rapidly brought to 100 microns of Hq. absolute. Heating plate temperatures were set at 130^{o}F for 16 hours (carrots, onions), or 24 hours (beef, pineapple, apples) or 30 hours (strawberries). The vacuum was broken with nitrogen gas, trays were removed, and product immediately packaged. The dried foods were put into a large double walled polyethylene bag (4 mils per wall thickness) under a steady bleed of nitrogen gas into the inner bag bottom. Each bag was then sealed and stored for at least one week to induce moisture equalization. Then the food was filled into cans, the cans evacuated, flushed with nitrogen and sealed.

More specific information on the foods is listed below:

a. Rice-Beef-Pea Casserole

The Minute Rice was purchased locally from a retail store.

The beef was purchased fresh. Before freeze drying, the fat was carefully cut from the beef, which was then cooked (150°F) with steam heat for 15 minutes and frozen.

After freeze drying, the beef was cut into 1/4" cubes and infiltrated with Myverol 1800 (Distillation Products Industries) by the vacuum release method. The method involves submerging the beef in hot (180°F) Myverol 1800, pulling a 30" Hg vacuum and releasing for three consective cycles.

Frozen peas were cooked for 5 minutes in boiling water and then air dried (dry bulb - 160°F, wet bulb - 94°F) for 2 1/2 hours.

b. Freeze Dried Strawberries

Fresh processing berries (the caps removed in the field) were purchased locally and then cleaned, sorted and frozen whole.

c. Freeze Dried Carrots

Frozen diced carrots were purchased from a local wholesaler.

d. Freeze Dried Onions

Fresh onions were purchased from a local wholesaler, and then sliced and frozen in-house.

e. Freeze Dried Pineapple

Fresh pineapple was obtained from a local wholesaler, and then processed and frozen in-house.

f. Freeze Dried Cooked Ground Beef

The meat was prepared according to QMC specification, LP/P, DES C-182-62 20 June 1962 and frozen in-house.

g. Low Moisture Raisins

Raisins at approximately 16% moisture content were vacuum dried 17 hours (60°C, approximately 29" Hg) to 1.5% moisture content, and stored in sealed glass jars prior to use.

2. Pre-Conditioning

Some extremely dry foods cannot be formed into acceptable compact shapes unless allowed to absorb small amounts of moisture. In Phase I, this was done where necessary by simply exposing the foods to the atmosphere for a short time until the desired moisture level was attained. For Phase II, however, a procedure allowing more control on the amount of absorption was utilized: the foods were placed in vacuum desiccators containing 200 ml of tap water in the bottom and by pulling a vacuum for various lengths of time. Noted below is a table listing the moisture pre-conditioning characteristics of the dried foods:

	Amt. (gm)	Moisture Content Before Pre-Conditioning (% Dry Basis)	Moisture Content After Pre-Conditioning (% Dry Basis)
Pre-Cooked Rice	170	10.12	15.69
Freeze Dried Carrots (Diced)	30	0.42	6.60
Freeze Dried Strawberries (Powdered)	20	1.50	4.14

The freeze dried strawberries were chopped up into powdered form to facilitate compression.

Due to a relatively low affinity for moisture, the rice in the rice-beef-pea casserole had to be under a vacuum for 9 hours to absorb the required amount of moisture. The freeze dried foods, on the other hand, having a much higher affinity for moisture were under vacuum only until a 29" Hg vacuum was drawn in the case of the strawberries and for 15 minutes in the case of the carrots; when the proper time had been reached, the vacuum was released.

Another form of pre-conditioning used was to alter the temperature of the product prior to compression. The vacuum dried raisins was the only food for which this was necessary (Phase I). After chopping up the hard brittle raisins in a nut chopper, they were placed in a 212°F natural convection oven for eight minutes.

3. Formation of Compacted Foods

a. Compressed Foods

A standard Carver Laboratory Hydraulic Press (Model B) with a supplementary low range pressure gauge was used in making the compacted foods. All of the compression work in Phase I was accomplished with a cylindrical die furnished with the Carver Press as a standard accessory and having a 4 square inch flat surface area. In Phase II the rice-beef-pea casserole and freeze dried strawberry and carrot bars were made with a rectangular die having a 0.875 sq. inch flat surface area (1/2" x 1 3/4" dimensions).

Another rectangular die having 2.19 sq. inch flat surface area (1 1/4" x 1 3/4" dimensions) was also used to make freeze dried carrot bars. The 4.000 and 0.875 square inch flat surface area dies were used in experiments with dehydrated meat and nonfat milk solids, respectively.

To aid in compressing very low density materials such as freeze dried foods, circular and rectangular auxiliary loading dies were set on top of their respective dies to handle the added volume (Figure 1). Then spacers were used to put the product through the auxiliary loading dies into the female dies. This method permitted the compression of low density materials in one continuous operation and eliminated undesirable preliminary partial compressions.

b. Molded Foods

Work with the molded foods was limited to Phase I. For the initial work a mold as such was not used; i.e., disks were formed manually.

In developing the built-in mechanism for softening and the subsequent preparation of the molded foods for the storage tests, an apparatus was constructed as shown in Figure 2. The frame of the apparatus consisted of three aluminum plates which could be screwed or pressed together. In between these plates were placed aluminum rings 50.8mm ID, into which the food was placed. Removal of the molded foods from the rings was made considerably easier by lining the rings with Teflon tape and removing the food while it was still warm.

B. Evaluation Procedures

The evaluation procedures noted here will be limited to those used in the exploratory work for Phases I and II. These procedures were designed to aid in evaluating or defining the physical characteristics of the disks and in particular hardness and/or rehydratability.

1. Hardness (bitability) was measured by the subjective evaluation of laboratory personnel actually trying to bite through the compacted foods. The following four-point scale was set up to aid in defining the degree of hardness:

Extremely hard	-	no penetration of incisors
Very hard	-	slight penetration of incisors
Moderately hard	-	penetration with some difficulty
Slightly hard	-	penetration with ease

Compacted foods that were "extremely" or "very" hard were classified as unbitable, and those that were "moderately" or "slightly" hard as bitable.

2. Cohesiveness has been evaluated subjectively according to appearance and handling properties. The following scale was set up for grading purposes:

   Excellent - no fragmentation or sloughing off of compacted material.

   Good - small degree of fragmentation or sloughing off of compacted material.

   Fair - moderate degree of fragmentation of compacted material.

   A grade of less than "Good" was not considered sufficiently cohesive to withstand normal handling without breakage or erosion.

3. Rehydratability was the length of time to rehydrate 100% or, when this was greater than 30 minutes, the percent rehydration. The latter was calculated by removing the rehydrated portion and measuring the volume of the remaining unrehydrated material, dividing by the total volume and subtracting from 100. In Phase I, both 170°F and 78°F tap water was used. For Phase II only the 170°F water was used.

   A wire basket, 3" in diameter, with a handle and wire lid was made and used for rehydrating compacted foods that had a specific gravity of less than 1.0 and consequently floated (Figure 3).

III. RESULTS AND DISCUSSION, PHASE I

A. Development of Built-In Mechanisms

Several mechanisms were experimented with: lamination, perforation, dry ice inclusion, pelletizing, and use of chemicals. Of these, lamination was the most promising. In the most general terms, the lamination mechanism involved making thin compact chips (laminates) and sticking them together by compression and/or other means.

The laminating mechanism is a physical one. The thicker food shapes, which are unbitable, are "softened" because they are made up of a series of thin laminates which are individually bitable and rehydratable. With the compressed foods, in order to get a realistic comparison of the laminated shapes with the solid, non-laminated shapes, the highest compression used in making the former was also used in making the latter.

The effectiveness of the mechanism depends on a critical dimension. The critical dimension in this case is that measure beyond which the food is too difficult to rehydrate and/or too hard to bite through. The critical dimension was found to depend on the compression level and moisture content of a particular food.

1. Lamination Mechanism

The development of the laminating mechanism for the ten foods noted in "Selection and Preparation of Foods" is outlined below.

a. Low Moisture Raisins

As the chopped low moisture raisins (1.50%) were quite hydroscopic, an attempt was made to utilize low humidity conditions. Corn starch was brushed on the surface of the die prior to compression to prevent the compacted raisins from sticking to the die.

To establish the critical dimensions, a two way table (Table 5) was set up. The variables were, pressure (750 to 5000 psi), and weight (10 to 14 gm).

The 11.5 gm/5000 psi laminate was selected for lamination because it appeared to possess the proper critical dimension characteristics and to have the proper thickness dimensions such that four laminated together would result in a disk 12.7mm (1/2 in.) thick. The details on the 11.5 gm/5000 psi laminate are noted in Table 3.

Disks consisting of four of the aforementioned laminates per disk were made up. The final compression treatments were 750, 500 and 100 psi. A thin layer of corn starch (0.1 gm) was used between the laminates compressed together at 750 and 500 psi to aid in

their separation later on. The results of the separation were as follows:

Pressure to laminate (psi)	750	500	100
Starch used between laminates	Yes	Yes	No
Separability	OK	OK	Difficult

It appears that using starch in between the individual laminates is essential in order to separate them. On the basis of the above results the 500 psi pressure to laminate was selected. The specifications for the laminated low moisture raisin disks are noted in Table 4.

The characteristics of the control disk (the disk without the built-in softening mechanism) are noted in Table 2.

b. Freeze Dried Carrots

Studies to establish the critical dimensions with the freeze dried carrots were done on an unknown variety of carrots at 2.70% moisture content. The variables in the two way table (Table 6) were, pressure (750 to 5000 psi), and weight (3 to 12 gm). The 6.0 gm/2500 psi laminate was selected because it appeared to have the proper dimension such that five laminated together would result in a disk 12.7mm (1/2 in.) thick and to satisfy the critical dimension requirements.

When a new batch of carrots of known variety was dried it was found to have different compression characteristics than the initial batch. Even raising the moisture content from 2.70% to 4.33% failed to match the results achieved with the initial lot of carrots. Further studies with the new lot of carrots at 4.33% moisture content revealed that by changing the weight per laminate from 6.0 gm to 5.0 gm all of the other specifications could be met (Table 3).

The laminates expanded after compression. Consequently, when an attempt was made to push the laminates back into the die for lamination, they were damaged. To alleviate this problem, a holding die, very similar to the auxiliary loading tube was used. The holding die was made to fit the bottom of the die used for compression in such a manner that their inside diameters would match up physically. The laminates were pushed into the holding die which was then placed in a desiccator. This sequence was repeated until all of the laminates were made and then they were pushed back into the die used for compression and were laminated together. Figure 4 shows a desiccator (for use when necessary) holding die and the components of the die used for compression.

As the laminates would not stick together by pressure alone, a "glue" of some sort was needed. A 25% solution of corn syrup

sprayed onto the laminates while they were in the holding die was found to be effective. Concentrations higher than 25% resulted in an uneven spray when dispensed in a hand operated atomizer. The spray was applied only to the surface of the laminate that was flush with the end of the holding die and of course no syrup was sprayed on the last laminate.

It was found that in order to separate the laminates easily with a knife, a template had to be constructed so that only an inner circle 1 3/4" in diameter was open to the spray of the diluted solution of corn syrup. Furthermore, the amount of syrup sprayed on the laminates had to be varied, decreasing from the first laminate to the last: 1st, 0.015 gm; 2nd, 0.015 gm; 3rd, 0.010 gm; 4th, 0.005 gm; 5th, 0.000 gm.

Decreasing the amount of corn syrup solution sprayed on the laminates as their number increased was done to compensate for the time lapse between the application of the spray on the first laminate and the fourth laminate (approximately 6 minutes). During larger scale production it was probable that equal amounts will be used.

Disks consisting of five of the 5 gm laminates per disk were made up. The final compression treatments were 500, 750 and 1250 psi. After storage in a closed container for a one hour holding period, the laminates were separated using a knife and characterized:

Pressure to laminate (psi)	500	750	1250
Rehydration Time (min.)			
78°F - 100%	13.5	17.0	21.0
170°F - 100%	3.25	3.50	5.00
Separability	OK	OK	Difficult

It appears that the final compression has a marked effect on the rehydratability of the laminates; the higher the pressure, the longer it takes the laminates to rehydrate. For the particular amounts of syrup sprayed between the laminates, a final compression of 1250 psi for 60 seconds apparently was too much. On the basis of the above results, the 500 psi pressure to laminate was selected. The specification for the laminated freeze dried carrot disks are noted in Table 4.

The characteristics of the control disk (the disk without the built-in softening mechanism)are noted in Table 2. The auxiliary loading tube was used to compress the control disk.

c. Air Dried Cabbage Flakes

To establish the critical dimensions for hardness and rehydratability of the air-dried cabbage flakes (4.80% moisture content), a two-way table (Table 7) was set up. The variables were, pressure (750 to 5000 psi), and weight (4 to 20 gm).

The 5.5 gm/2500 psi laminate was selected for lamination. The cabbage flakes were preconditioned at 175°F for 5 minutes prior to compression. Then seven laminates each were compressed into disks at 1250, 2500, and 5000 psi. After two days at 100°F storage in sealed glass jars, the laminates of the three disks had separated. To prevent the separation, 25% corn syrup solution was sprayed onto the laminates. Immediately following the loading of each laminate into the holding die, the surface of each laminate was sprayed with 0.1 gm syrup. Pressure to laminate was 2500 psi. The laminates stuck together and were separated with little or no difficulty after one day storage at 100°F but the individual laminates were easily broken.

To make the 5.5 gm laminates more cohesive, a 6.5% concentration of thin boiling starch (50-63 fluidity) obtained from Corn Products Company was sprayed (1.96%) on 50 gm lots of cabbage flakes prior to preconditioning at 175°F for 5 minutes and compression at 2500 psi. The solution was prepared by boiling at 180°F for 10 minutes and was dispensed in a hand-operated atomizer. Pressure to laminate (number of laminates: 7) was 2500 psi. After one hour storage at 100°F, the laminates had separated, but the laminates possessed excellent cohesiveness.

To improve the adherence of the laminates to each other and concurrently to improve the cohesiveness of the individual laminates, a 6.5% concentration of the thin boiling starch was made up and sprayed (2.04% by weight) on the cabbage flakes prior to compression (2500 psi). The preconditioning (heating) was eliminated because it minimized the "gluing" effect of the starch solution. Pressure to laminate (number of laminates: 7) was 2500 psi. After two days at 100°F storage, the laminates had not separated. The thickness of the laminated disk as measured after compression was 10.2mm.

The gram per laminate level was increased to 6.2 because the individual laminate then appeared to have the proper dimension such that seven laminated together would result in a disk 12.7mm (1/2 in.) thick. The details on the 6.2 gm/2500 psi laminate are noted in Table 3.

The laminates expanded after compression. Consequently, the holding die noted in the discussion under freeze dried carrots was used to facilitate the laminating operation.

Disks consisting of seven of the aforementioned laminates per disk were made up. The final compression treatments were 1250, 2500 and 5000 psi. After storage in a closed container for a one hour

holding period the laminates were separated using a knife and characterized:

Pressure to laminate (psi)	1250	2500	5000
Rehydration Time (min.)			
78°F - 100%	15.5	16.5	18.5
170°F - 100%	0.50	0.50	0.75

It appears that the final compression has a marked effect on the rehydratability of the laminates; the higher the pressure, the longer it takes the laminates to rehydrate. On the basis of the above results, the 1250 psi pressure to laminate was selected. The details on the laminated air dried cabbage disks are noted in Table 4.

The characteristics of the control disk are noted in Table 2.

d. Freeze Dried Apples

To establish the critical dimensions of the freeze dried apples (1.42% moisture content) a two-way table (Table 8) was set up. The variables were, pressure (750 to 5000 psi), and weight (4 to 12 gm).

The 5.0 gm/2500 psi laminate was selected for initial lamination studies.

Two groups of seven laminates were compressed together at 2500 and 750 psi, respectively. The reaction between the humidity in the air and the sugar in the apples was utilized as the adherent. After one hour in the desiccator it was impossible to separate the laminates compressed at 2500 psi (disk thickness - 11.4mm) and very difficult to separate the laminates compressed at 750 psi (disk thickness - 13.2mm)

To be able to separate the laminates and concurrently to construct a laminated disk 12.7mm thick, the pressure range for laminating was dropped to 500 and 250 psi, the number of laminates was lowered to six and the number of grams per laminate was raised to 5.25. The disk thicknesses, in order of decreasing laminating pressure, were 11.6 and 12.7mm respectively. After a one hour holding period in the desiccator it was very difficult to separate the laminates compressed together at 750 psi, but the compression levels of 500 psi and 250 psi were not sufficient to make all of the laminates in the two respective disks stick together.

On the basis of the above results, the 250 psi pressure to laminate was selected. The specifications on the 5.25 gm/2500 psi laminate are noted in Table 3.

The laminates expanded after compression. Consequently, the holding die noted in the discussion under freeze dried carrots was used to facilitate the laminating operation.

At the lower pressure levels the moisture in the air was apparently not enough to make the laminates adhere to each other. Consequently, a procedure was developed whereby additional moisture was added to the laminates.

The procedure consists of a template in the shape of a disk with a 3/4" diameter hole in the center and made to fit over the holding die. This is illustrated in Figure 5. A fine spray of water was dispensed from a hand operated atomizer onto the 3/4" diameter exposed surface of the apple laminates. The amount of water applied to each laminate was varied due to the time lapse in the laminating procedure: 1st, 0.0020 gm; 2nd, 0.0020 gm; 3rd, 0.0015 gm; 4th, 0.0015 gm; 6th, 0.0000 gm. During larger scale production it is probable that equal amounts will be used.

After compression and subsequent expansion the individual laminates of the disks were not very distinguishable. Consequently, a 1% solution of French's Certified Green Food Color was prepared and two small drops (<0.0001 gm) applied to opposite edges of the first through fifth laminates after they were pushed into the holding die. A laminated apple disk marked thusly is illustrated in Figure 3.

The details on the laminated freeze dried apple disks are summarized in Table 4.

Characteristics of the control disk are found in Table 2. The auxiliary loading tube was used to compress the control disks.

The laminated disk is less dense than the control disk. This is due primarily to the fact that while the laminates were in the holding die, they expanded and the final compression was not sufficient to correct for this. During large scale production it is probable that the operation will be such that the expansion will be kept to a minimum and that the densities of the control disk and the laminated disk will be the same.

e. Freeze Dried Strawberries

To establish the critical dimensions for freeze dried strawberries (4.48% moisture content), a two-way table (Table 9) was set up. The variables were, pressure (250 to 2500 psi), and weight (4 to 6 gm). In order to successfully compress the strawberries, they had to be chopped up in a nut chopper. As the chopped strawberries were quite hygroscopic, they were chopped just before compression. The chopper was placed in a desiccator when not in use.

A 5.0 gm/500 psi laminate was selected for initial lamination studies. The reaction between the humidity in the air and the sugar in the strawberries was utilized as the adherent. Six such laminates were compressed together at 500 psi (disk thickness - 11.2mm). After one hour in the desiccator it was impossible to separate the laminates.

To permit separation of the laminates and concurrently to construct a laminated disk 12.7mm thick the pressure for laminating was dropped to 250 psi, the weight of material per laminate was reduced to 4.5 grams and the number of laminates was increased to seven. The disk thickness after compression was 13.1mm. After a one hour holding period in the desiccator the laminates were very difficult to separate.

In a further, and this time successful, attempt to make the laminates separable and of the desired thickness (12.7mm or 1/2 in.), the pressure for laminating was dropped to 100 psi, and the number of grams per laminate was reduced to 4.3. The 4.3 gm/500 psi laminate is characterized in Table 3.

The laminates expanded after compression. Consequently, the holding die noted in the discussion under freeze dried carrots was used to facilitate the laminating operation.

After compression and subsequent expansion the laminates of the laminated disks were not very distinguishable. Consequently, a 1% solution of French's Certified Red Food Color was prepared and two small drops (0.001 gm) applied to opposite edges of the first through fifth laminates after they were pushed into the holding die.

The details on the laminated freeze dried strawberry disks are summarized in Table 4.

Characteristics of the control disk are found in Table 2. The auxiliary loading tube was used to compress the control disks.

The laminated disk is less dense than the control disk. This is due primarily to the fact that while the laminates were in the holding die they expanded and the final compression was not sufficent to correct for this. During large scale production it is probable that the operation will be such that the expansion will be kept to a minimum and that the densities of the control disk and the laminated disk will be the same.

f. Freeze Dried Onions

To establish the critical dimensions for freeze dried onions (1.97% moisture content), the two way table (Table 10) was devised. The variables were pressure (750 to 5000 psi) and weight of onions (4 to 8 gm).

The 6.0 gm/2500 laminate was selected for initial lamination studies. Seven laminates were compressed together at 3750 psi. The disk thickness was 15.4mm. The laminating pressure was not sufficient nor was the moisture in the air adequate to make the laminates adhere together.

As the laminates would not stick together by pressure alone, a "glue" of some sort was needed. A fine spray of water applied to the laminates while they were in the holding die was found to be effective. The application of the fine spray of water was the same as described earlier under freeze dried apples. The amount of water applied to each laminate was varied due to the time lapse in the laminating procedure: 1st, 0.0015 gm; 2nd, 0.0015 gm, 3rd, 0.0015 gm; 4th, 0.0004 gm; 5th, 0.0004 gm; 6th, 0.0000 gm.

In an attempt to achieve a laminated disk thickness of 12.7mm, the number of laminates was reduced by one, the pressure to make each of the remaining six laminates was increased to 3750 psi and the pressure to laminate them together was increased to 5000 psi. After the final compression the laminated disk thickness was 12.7mm. The laminates were easily separated with a knife after an hour holding period in the desiccator. The 6.0 gm/3750 psi laminate is characterized in Table 3.

The laminates expanded after compression. Consequently, the holding die noted in the discussion of freeze dried carrots was used to facilitate the laminating operation.

After compression and subsequent expansion the laminates of the laminated disk were not easily distinguishable. Consequently, a 0.1% solution of FD&C Green No. 1 was prepared and one small drop (0.0001 gm) was applied to an edge of the first through fifth laminates after they were individually pushed into the holding die.

The details on the laminated freeze dried onion disks are summarized in Table 4.

The specifications for the control disk are given in Table 2. The auxiliary loading tube was used in compressing the control disk.

g. Freeze Dried Pineapple

A two-way table (Table 11) was evolved to evaluate the critical dimensions for the freeze dried pineapple (2.77% moisture content). The variables were, pressure (525 and 1250 psi), and weight (5 to 6 gm).

In order to successfully compress the pineapple into a uniform product, larger pieces had to be chopped up to a coarse powder in a nut chopper. As the chopped pineapple was quite hygroscopic, it was chopped just before compression. The chopper was placed in a desiccator when not in use.

The laminates expanded after compression. Consequently, the holding die noted in the discussion under freeze dried carrots was used to facilitate the laminating operation. Corn starch was brushed on the surface of the die prior to compression to prevent the laminated disks from sticking to the die.

For the initial lamination studies, the 5.5 gm/1250 psi laminate was selected. Six laminates were compressed together at 750 psi. A light coat of corn starch was brushed on the exposed surface of the laminates immediately after they had been pushed into the holding die. The thickness of the laminated disk was 11.5mm. After an hour holding period in the desiccator the laminates were easily separated with a knife.

In an attempt to achieve a laminated disk 12.7mm thick, the weight of material per laminate was increased to 5.6 grams and the pressure to laminate them together was decreased to 525 psi. The pressure to make the laminates remained the same. Corn starch (0.1 gm) was brushed on as described above. The thickness of the laminated disk was 12.7mm x 57.4mm. The laminates were easily separated with a knife after an hour holding period in the desiccator. The details of the 5.6 gm laminate are noted in Table 3.

After compression and subsequent expansion, the individual laminates of the disks were not very distinguishable. Consequently, a 0.1% solution of FD&C Yellow No. 5 was prepared and one small drop (0.001 gm) was applied to an edge of the first through fifth laminates after they had been individually pushed into the holding die.

The details on the laminated freeze dried pineapple disks are summarized in Table 4.

Specifications for the control disk are given in Table 2.

The laminated disk is less dense than the control disk. This is due primarily to the fact that while the laminates were in the holding die, they expanded vertically and the final compression was not sufficient to correct for this.

h. Quaker Oats Puffed Rice

An aliquot taken from a newly opened package was impossible to compress into a cohesive disk because of the low moisture content. After exposure to a relative humidity of 62% for 15 minutes, there was enough moisture pick-up so that compression resulted in a reasonably cohesive disk. The pre-conditioned cereal was allowed to equilibrate under nitrogen for two weeks in a double-walled polyethylene bag (4 mills per wall). An analysis of the Puffed Rice indicated that the moisture content was 6.45%.

To establish the critical dimensions a two-way table (Table 12) was set up. The variables were, pressure (1250 to 5000 psi) and weight (3 to 6 gm).

The laminates expanded after compression. Consequently, the holding die noted in the discussion under freeze dried carrots was used to facilitate the laminating operation.

The 4.0 gm/5000 psi laminate was chosen for initial lamination studies. Six laminates were compressed together at 750 psi for 60 seconds. The disk thickness was 13.4mm. A fine spray of water was applied to the laminates while they were in the holding die. The spray was applied only to the surface of the laminate that was flush with the end of the holding die and no water was sprayed on the last laminate. The added moisture between the laminates was not enough to make them stick together, however.

In an attempt to achieve a laminated disk thickness of 12.7mm the final pressure was increased to 2500 psi. To make the laminates stick together, a fine spray of 25% solution of corn syrup was applied to two laminates in the manner described above. The disk thickness was 12.1mm. The dilute corn syrup solution was not adequate to make the laminates adhere together either.

The third, and this time successful, attempt to develop a laminated disk 12.7mm thick resulted when the final pressure was decreased from 2500 to 1250. For a successful means of making the laminates stick together a 0.024 gm drop of corn syrup was placed on each laminate whose surface was flush with that of the holding die. After an hour holding period in the desiccator the laminates were easily separated with a knife. The 4.0 gm/5000 psi laminate is characterized in Table 3.

Details on the laminated freeze dried Puffed Rice disks are summarized in Table 4.

The control disk is characterized in Table 2. The auxiliary loading tube was used in compressing the control disk.

The laminated disk is less dense than the control disk. This is due primarily to the fact that while the laminates were in the holding die, they expanded vertically and the final compression was not sufficient to correct for this.

i. Molded Foods

Basically, two types of molded foods were investigated: (1) a confectionery product, and (2) a bakery product. The application of the laminating mechanisms to these two foods is discussed below.

(1) <u>Confectionery - High Cook Caramel</u>

The following formula is a modification of a standard caramel formula in that the salt was omitted:

25 gm	Margarine
6 gm	Lecithin
200 gm	Corn syrup
100 gm	Granulated sugar
250 gm	Sweetened condensed milk
20 gm	water

The margarine and lecithin were melted and mixed together. Then the corn syrup, sugar and water were added. The resulting mix was heated to a boil with constant stirring, and then the milk was slowly added. Cooking was continued until a temperature of 260°F was reached and the mix was poured into the molds.

After the candy was poured into the molds, a compression operation took place; i.e., the caramel filled rings containing excess caramel were placed between the plates and compressed at 40 psi.

After the caramel had cooled to 90°F - 100°F, the pressure was released and the disks were pushed out of the rings. It was found that if the plates were not preheated to approximately 250°F it was impossible to press the excess candy out of the rings.

The molded caramel disks were removed from the rings while they were still warm and allowed to cool.

Disks 12.7mm thick were extremely hard, unbitable. Yet, 2.4mm thick disks were moderately hard, or bitable; they were brittle and pieces could be broken with the incisors.

An attempt was made to produce a 12.7mm laminated disk by compressing five of the above laminates together after they had been softened slightly in a 120°F oven. The laminates were compressed together at 25 psi for 5 seconds. After one day at 100°F storage it was impossible to separate the laminates. Even when a light coat of corn starch was brushed on the adjacent surfaces of the laminates, it was impossible to separate the laminates without breaking them.

To decrease the contacting surface area of the laminates and to increase the amount of corn starch on the laminates, the adjacent faces of the laminates were scratched with a knife. After the corn starch was brushed on, the laminates were preheated and then compressed together at 25 psi for 5 seconds

and stored for one day at 100°F. Several of the laminates broke when an attempt was made to separate them.

It appeared that a better method of reducing the contacting surface area was needed. Three square inch pieces of 30, 40 and 50 mesh brass screen were soldered to five square inch plates of galvanized steel 1/16 inch thick. Then, experimenting with different pressures, it was found that compressing the preheated laminates individually between the plates at 250 psi for 5 to 15 seconds depending on the softness of the caramel gave the best results. Of the three grades of screen the 50 mesh screen produced the best grid. It was not felt that a finer grid would be of any value.

Five preheated laminates, with the 50 mesh grid and 0.5 gm of corn starch brushed on adjacent surfaces, were compressed together at 25 psi for 5 seconds. After 100°F storage for 24 hours the laminated disk was allowed to come to room temperature and an attempt was made to separate the laminates. Two laminates were broken in the process. Another way was needed to make the laminates stick together.

Three holes, 0.120 inches in diameter were drilled into five caramel laminates stacked one on top of the other. The holes were drilled an equidistant 7/8 inch apart and 5/8 inch from the edge of the laminates. Into the holes a portion of the following formula was dispensed from a 40 minim syringe minus the needle:

19 gm	margarine
96 gm	confectioners sugar
16 gm	whipping cream

The filler material was allowed to harden undisturbed. The effect was analogous to using three dowels to hold the laminates together. After storage at 100°F for 24 hours the laminates were easily separated with a knife.

The specifics on the 2.4mm laminate are noted in Table 3.

Details on the laminated high cook caramel disks are summarized in Table 4.

The control disk is characterized in Table 2.

(2) <u>Bakery - Non-leavened Cookie</u>

The formual below is a completely restyled version of a standard cookie formula. The original formula included shortening, soda, salt, cinnamon, ginger, allspice, raisins and oatmeal.

The shortening and soda are softening agents and were consequently left out. The condiments were not deemed necessary. The raisins and oatmeal interferred with the molding operation and thus were omitted.

All of the ingredients used were increased by varying amounts except the flour. The flour was decreased to a more realistic value in relation to the other ingredients.

250 gm	granulated sugar
25 gm	non-fat dry milk solid
50 gm	eggs (one egg)
100 gm	molasses
25 gm	water
285 gm	flour

The sugar and milk powder were mixed together. Then the molasses, water and eggs were stirred into the mix followed by the flour. After the dough had been sufficiently kneaded it was pushed into the 50.8mm ID molds. The loaded molds were then placed between the aluminum plates. After screwing down the plates the dough was baked in a standard cooking oven at 375°F. To aid in removing the disks from the aluminum frame, strips of Teflon tape were laid down on the plates. The molded cookie disks were removed from the rings while they were still warm and allowed to cool.

Disks 12.7mm thick were extremely hard, unbitable; yet, 3.2mm thick disks were moderately hard, or bitable. (The 3.2mm thick disks were baked for 38 minutes while the 12.7mm thick disks were baked for 45 minutes.)

The mechanism used to make the caramel laminates stick together was carried over to the cookie laminates. Three holes, 0.1200 inch in diameter, were drilled into four laminates which had previously been preheated to 120°F and compressed together at 25 psi for 5 seconds. The holes were drilled an equidistant 7/8 inch apart and 5/8 inch from the edge of the laminates. The same filler material noted in the discussion of the caramel laminates was used to fill the holes from a 40 minim syringe minus the needle. As before, the filler material was allowed to harden undisturbed. After storage at 100°F for 24 hours the laminates were easily separated with a knife.

The characteristics of the 3.2mm laminate are noted in Table 3.

Details on the laminated non-leavened cookie disks are summarized in Table 4.

The control disk is characterized in Table 2.

2. Perforation Mechanism

a. Drilling

A drill press was used for drilling the holes in the disks. The control disks mentioned under the previous discussions of the laminating mechanism and noted in Table 2 were used to test out this built-in mechanism.

(1) Air Dried Cabbage (4.80% moisture content)

Using a 0.081 in. drill, holes were drilled in a 1/4 in. grid through the top of a control disk.

After drilling, 5% of the weight of the disk was calculated to have been removed. The disk remained extremely hard.

A 0.114 inch drill was used to drill holes in the same grid pattern through similar disks. The drilling caused a reduction in 7% of the weight of the disk. There was no softening effect noted; the disks were extremely hard before and after drilling. Therefore, investigation of the drilling mechanism was discontinued for the cabbage disks.

(2) Freeze Dried Carrots (4.33% moisture content)

A 0.081 in. drill was used to drill holes in a 1/4 in. grid through the top of a control disk.

It was impossible to drill more than two holes before the bottom half of the disk began coming apart. Consequently, use of the drilling mechanism was not considered feasible with the compacted freeze-dried carrot disks.

(3) Freeze Dried Pineapple - Granulated (2.77% moisture content)

Using a 0.081 in. drill, holes were drilled in a 1/4 in. grid through the top of a control disk.

After drilling, 16.5% of the weight of the disk was gone and it was still impossible to bite through the disk. The make matters worse the drill was filled with crystallized pineapple. Therefore, investigation of the drilling mechanism was discontinued for the pineapple disks.

(4) Freeze Dried Onions (1.97% moisture content)

A 0.081 in. drill and drill press were used to drill holes in a 3/8 in. grid through the top of a control disk, similar to one described above. It was impossible to complete more than three

holes before the disk split. Consequently, use of the drilling mechanism was not considered feasible with the compacted onion disk.

(5) High Cook Caramel

A 0.052 in. drill was used to drill holes in a 1/4 in. grid arrangement through the top of a control disk. The drilling operation removed 18.5% of the caramel disk. The disk was still impossible to bite. Even drilling two rows of holes through the side removing an additional 11.5% of the total weight of the disk did not make the disk bitable.

A 0.089 in. drill was used to drill holes in the same grid arrangement without any success. It was impossible to drill any holes through the caramel when the drill size was increased to 0.120 in. because the caramel would break. Therefore, drilling was discarded as a possible mechanism for softening caramel disks.

(6) Non-Leavened Cookies

A 0.086 in. drill was used to drill a 1/4 in. grid through the top of a control disk. The drilling operation removed 11.5% of the cookie disk. The disk was still impossible to bite. Even drilling two rows of holes through the side removing an additional 7.8% of the total weight of the disk did not make the disk bitable. Consequently, drilling was discarded as a possible mechanism for softening cookie disks.

b. Die Formed Holes

The device consisted of three parts: (1) a ram, (2) a cylinder and (3) a spiked plate with spacer. The ram and cylinder are self descriptive. The spiked plate was made up of a 1/2 in. thick steel disk, 50.8mm in diameter into which were fixed 1/8 in. spikes (10° taper) arranged in a 1/4 in. grid. A 1/8 in. thick perforated aluminum spacer was placed on the spikes between the steel disk and food so that the food could be pried off of the spikes after compression. Noted below are disks containing die-formed holes.

(1) Freeze Dried Onions (1.97% moisture content)

Disk Weight:	27.0 gm
Pressure and Dwell (psi/sec):	5000/60
Disk Dimensions:	12.7mm x 51.2mm
Disk Cohesiveness:	excellent
Disk Hardness:	extreme
Disk Rehydration (71°F-100%):	>30 min.
Density after Compression	1.033 gm/cc

It was not easy to remove the compressed food from the spikes. If the disk was not as hard as it was it would probably have fallen apart when an attempt was made to remove it from the spikes. Consequently, use of the built-in holes mechanism was not considered feasible with freeze-dried onions.

(2) Freeze-Dried Pineapple (moisture content: 2.77%)

Disk Weight:	28.0 gm
Pressure and Dwell (psi/sec):	1250/60
Disk Dimensions:	12.6mm x 51.3mm
Disk Cohesiveness:	excellent
Disk Hardness:	extreme
Disk Rehydration (78°F-110%):	>30 min.
Density after Compression:	1.075 gm/cc

As with the onions, the compressed pineapple was not easily removed from the spikes. It appeared that the only way to decrease the hardness would be to lower the density and this would probably make it impossible to remove the disk from the spike without destroying the disk. Thus the built-in holes mechanism was not considered feasible with freeze-dried pineapple.

(3) Freeze-Dried Carrots (moisture content: 4.33%)

Disk Weight:	21.0 gm
Pressure and Dwell (psi/sec):	2500/60
Disk Dimensions:	12.7mm x 51.3mm
Disk Cohesiveness:	excellent
Disk Hardness:	extreme
Disk Rehydration (78°F-100%):	>30 min.
Density after Compression:	0.800 gm/cc

The built-in holes mechanism did not appear to have any effect on softening nor did it appear to result in any increase in the rate of rehydration. Therefore the use of this mechanism was not considered feasible with freeze-dried carrots.

(4) Freeze-Dried Strawberries (moisture content: 3.93%)

Disk Weight:	20.0 gm
Pressure and Dwell (psi/sec):	500/60
Disk Dimensions:	12.7mm x 51.2mm
Disk Cohesiveness:	excellent
Disk Hardness:	extreme
Disk Rehydration (78°F-100%):	>30 min.
Density after Compression:	0.765 gm/cc

The results noted above of an attempt to apply the built-in holes mechanism to strawberries were essentially the same as reported for onions, pineapple and carrots; the comments per-

taining to those foods could apply equally as well to strawberries. Consequently, use of the built-in holes mechanism was not considered feasible with freeze-dried strawberries.

(5) Freeze-Dried Apples (moisture content: 2.39%)

Disk Weight:	21.5 gm
Pressure and Dwell (psi/sec):	2500/60
Disk Dimensions:	12.7mm x 51.2mm
Disk Cohesiveness:	poor
Disk Hardness:	slight
Density after Compression:	0.822 gm/cc

It was impossible to remove the disk from the spikes without loosing some of the compressed food. Therefore, the mechanism was not deemed to be feasible with freeze-dried apples.

3. Chemical Mechanism - Inclusion of Baking Powder

The inclusion of baking powder was thought to help accelerate the rehydration of the compact food disks. Freeze dried apples (1.97% moisture content) were the only food to which this mechanism was applied.

Baking powder was mixed with powdered freeze-dried apples to three levels: 20, 10 and 5%. The combined materials (total weight = 5 grams) were compressed at 2500 psi for 60 seconds. The respective dimensions were 2.0mm x 57.8mm, 1.7mm x 57.5mm and 1.8mm x 57.7mm. The following table shows the percent of baking powder and the corresponding rehydration time in 78°F water for the disks:

% Baking Powder	Rehydration Time (min.)
20	8
10	8
5	12
0	13

The disk containing 0% baking powder measured 2.1mm x 57.8mm. The eating quality of the 20% and 10% baking powder disks was very poor. The disk at the 5% level possessed good eating quality. However, there was only a slight reduction in rehydration time from the standard of 13 minutes. Thus the use of baking powder was not considered of value as a means of accelerating the rehydration of apple disks and further work with a chemical mechanism was discontinued.

4. Inclusion of Dry Ice Mechanism

It was thought that the inclusion of powdered dry ice just prior to compression might, after sublimation, act as a built-in mechanism to physically soften and accelerate the rehydration of compacted food disks. This mechanism was applied to several foods.

a. Freeze Dried Onions (1.97% moisture content)

In preliminary investigation nine grams of powdered dry ice were mixed with twenty-seven grams of powdered onions and the mixture was compressed at 5000 psi for 60 seconds. The upper one third of the disk separated from the rest. A blend of 18 gm of powdered dry ice and 36 gm of powdered onions compressed at 5000 psi for 60 seconds gave the same result. It appeared that the dry ice levels (equal to 25 and 33% of the onion weight) was too high to obtain cohesive disks.

Further investigations were conducted using lower levels of dry ice.

Total Weight Compressed (gm):	34.0	35.0	35.0
Ratio Onions/Dry Ice (%):	85/15	89/11	91/9
Pressure and Dwell (psi/sec):	5000/60	5000/60	5000/60
Disk Dimensions (after compression):	11.3x58.2mm	12.3x58.2mm	12.7x58.3mm
Disk Cohesiveness (after sublimation):	good	good	good
Disk Hardness (after sublimation):	moderate	moderate	moderate
Disk Rehydration (78°F-100%):	>30 min.	>30 min	>30 min
Density After Sublimation (gm/cc):	0.97	0.95	0.94

In comparison the characteristics of the control disk are noted in Table 2. The densities of the CO_2 treated disks after the sublimation of CO_2 (0.94 - 0.97 gm/cc) were lower than those of the control disk (1.06 gm/cc). Accomplishment of the hardness, based on equal density bars, is therefore not possible. However, a comparison based on compression conditions, would show that the incorporation of dry ice during compression reduces hardness. (The densities of the bars after compression and before the CO_2 sublimed averaged 1.07 gm/cc). The rate of rehydration, however, was not significantly aided by the "dry ice" mechanism. Therefore, no further attempt was made to apply the inclusion of dry ice to the freeze dried onion disks.

b. Freeze Dried Pineapple (2.77% moisture content)

The pineapple chunks were ground up in a nut chopper before adding the dry ice and the compression treatment.

Total Weight Compression (gm):	27	29
Ratio Pineapple/Dry Ice (%):	93/7	86/14
Pressure and Dwell (psi/sec):	2500/60	2500/60
Disk Dimensions (after compression):	12.7mm x 58.2mm	12.7mm x 58.2mm
Disk Cohesiveness (after sublimation):	excellent	excellent
Disk Hardness (after sublimation):	extreme	moderate (split along side)
Disk Rehydration (78°F-100%):	>30 min	-
Density after Sublimation (gm/cc):	0.74	-

The characteristics of the control disk are noted in Table 2 for comparison.

The dry ice did not appear to be applicable to the freeze-dried carrots. The effect of the dry ice was either too much (causing splitting) or too little (no decrease in hardness and no increase in rate of rehydration).

d. Freeze-Dried Strawberries (moisture content: 3.93%)

Total Weight Compressed (gm):	29.0	25.0
Ratio Strawberries/Dry Ice (%):	90/10	96/4
Pressure and Dwell (psi/sec):	500/50	500/60
Disk Dimensions (after compression):	15.0mm x 58.2mm	12.7mm x 58.2mm
Disk Cohesiveness (after sublimation):	good	excellent
Disk Hardness (after sublimation):	moderate (split along side)	moderate
Disk Rehydration (78°F-100%):	-	>30 min
Density after Sublimation (gm/cc):	-	0.71

For comparison, the characteristics of the control disks are noted in Table 2.

The densities of the treated and control disks were, for all practical purposes, the same. Therefore, it can be concluded that incorporation of the dry ice mechanism reduced the hardness of the bar but did not aid in speeding up rehydration.

e. Freeze-Dried Apples (moisture content: 2.39%)

Total Weight Compressed (gm):	40.0	34.0
Ratio Apples/Dry Ice (%):	75/25	85/15
Pressure and Dwell (psi/sec):	2500/60	2500/60
Disk Dimensions (after compression):	13.4mm x 57.8mm	12.8mm x 58.1mm
Disk Cohesiveness (after sublimation):	good	excellent
Disk Hardness (after sublimation):	slight (split along side)	moderate
Disk Rehydration (78°F-100%):	-	>30 min
Density after Sublimation (gm/cc):	0.85	0.86

The characteristics of the control disk are noted in Table 2 for comparison.

The results of freeze-dried apples were very similar to those obtained with the strawberries. Then density of the dry ice treated disk was very slightly lower than that of the untreated disk. Hardness was reduced by the dry ice mechanism, but rehydration characteristics were not improved.

5. <u>Pelletizing Mechanism</u>

Another attempt at developing a build-in mechanism for softening and for accelerating the rehydration of compacted food disks was to use small round shaped particles (pellets) compressed and held together by a

soluble protective film. As no tabletting machine was available, an attempt was made to produce pellets using the meat grinding attachment to a Hobart Mixer. It was thought that the screw would push the apple cubes through the plate so that the end result would be pellets. Instead, the screw crushed the apple cubes and then ground them with such force that they became jamed up in the screw (the motor was in low gear at the time). Consequently, no material went through the plate. No further attempts were made to develop this mechanism.

B. Storage Study

Four temperature conditions were used in the three-month test, as follows:

100°F
70°F
40°F
0 to 40°F (Temperature cycling, 2 cycles/wk, maximum 40°F, minimum 0°F)

All of the disks were stored in pint canning jars with two-piece metal lids (Ball Brothers) at atmospheric pressure and ambient relative humidity (50-60%).

A discussion of the results of the storage study for all of the foods immediately follow a brief description of each evaluation procedure.

1. Sensory Evaluation

From a pool of 20 people, taste panel of 10 each were selected for the following groups of foods (note exception of 8 people for onions and cabbage) on the basis of similarity in scoring and individual ability to duplicate results closely:

- caramel, cookie
- onions, cabbage (panel of 8 people)
- pineapple, strawberries
- carrots

The tasters evaluated the different groups of foods according to a hedonic scale. Coded samples (four), arranged in a randomized block design, were presented to the tasters at 10 a.m. and 3 p.m. (replicates). One day the control samples would be scored and the next day the experimental samples would be scored.

The procedures for preparation of the foods for tasting are as follows:

Freeze Dried Pineapple and Strawberry disks were ground up and the resulting material was passed through a U.S. #25 screen to disguise the softening mechanism. The particles of food that passed through the screen were presented to the panel.

Freeze Dried Onions and Air Dried Cabbage disks were broken up and rehydrated. To dilute the flavor intensity to an acceptable level, the resulting rehydrated material was added to

Durkee's Salad Dressing according to the formulas noted below:

	Onions	Cabbage
Salad Dressing (gm)	100	30
Rehydrated Food (gm)	70	80

High Cook Caramel and Non-Leavened Cookie disks were pulverized into small pieces and served to the panel.

Freeze Dried Carrots disks were ground up and rehydrated with hot (160°F) water.

In Tables 13 through 19 of the Appendix are noted the results of the statistical evaluations (4).

The taste panel could not detect any significant differences between the laminated and control disks with regards to flavor and odor for all of the foods except the high cook caramel where the difference for all practical purposes is not important.

Pineapple, strawberry, cabbage and caramel disks were all significantly affected by storage temperature, notably the 100°F temperatures. In fact the cabbage disks stored at 100°F were not tasted since they were so bad.

Tables 20 through 26 give the means for the main effects for all of the foods. Pineapple, strawberries, caramel and cookies were all accepted. The carrots, cabbage and onions were on the borderline between acceptable and unacceptable.

2. Color

Color was evaluated with a Perkin-Elmer Spectracord using M_gCO_3 as the reference material. The resulting reflectance curves were observed for significant differences between the control and laminated disks (presented as granulated samples) in the region of their predominant hues. Data on the percent reflectance at selected wavelengths is given in Tables 27 through 33.

The approximate lines corresponding with the wavelengths chosen are as follows:

	Wavelength Range mu	Hue Range
Pineapple	530 - 600	Yellowish green to reddish orange
Onions	490 - 580	Bluegreen to yellow
Cookies & Caramel	575 - 700	Yellow to red
Carrots	530 - 650	Yellowish green to red
Strawberries	580 - 700	Yellowish orange to red
Cabbage	490 - 665	Bluegreen to red

The reflectance data for the pineapple, onions, strawberries and cabbage at 0-months storage were essentially the same as the reflectance data for the samples stored at 0 to 40°F (cycling), 40°F and 70°F for three months. The values for percent reflectance at 100°F were all significantly lower indicating a darkening of the disks. There did not appear to be any significant changes in reflectance values attributable to the laminating mechanism.

Cookies At 0-months storage, the reflectance data were essentially the same as that for the samples stored at 0 to 40°F (cycling), 40°F, 70°F and 100°F for 3 months. Data for the control and laminated disks were essentially the same.

Caramel The reflectance data for the control disks at 0 months storage were essentially the same as the reflectance data for the control disk stored under the four specified temperature conditions for 3 months. The reflectance data for the laminated disks at 0-months storage, however, appeared to be significantly different than the data for the disks after the storage period. The high reflectance values at 0-months storage were no doubt due primarily to the incidence of the corn starch which faded to some extent over the storage period rather than any significant change in the color of the caramel itself.

Carrots The reflectance values for the carrots at 0-months storage were lower than those obtained for the samples stored at 0 to 40°F (cycling), 40°F, 70°F and 100°F for three months. The results indicate that the samples possessed a lighter color after storage than before storage as expected. Reflectance values were higher at 590 mu than before storage. Disks stored at 0 to 40°F (cycling), 70°F and 100°F temperatures were somewhat lighter than those at 40°F. As the storage temperature for the samples increased the difference between the reflectance values (590mu-orange) of the laminated and control disks decreased, with the laminated carrot samples showing less losses of beta carotene than the control samples.

3. Moisture

Moistures were determined in triplicate by vacuum the oven method (28" H_g, at 140°F for 16 hours).

The moisture contents before and after the three months storage period are noted in Tables 34 through 40. The difference in moisture content between the control and laminated disks before storage was expected for all of the foods. The reasons for the one or two percent fluctuations in moisture content of the stored samples was not apparent. The semi-weekly fluctuations in temperature (0 to 40°F) might have contributed to a loss of moisture in some cases, particularly for the laminated disks. Otherwise, the storage conditions did not seem to result in any drastic differences between the laminated and control samples.

4. Sugars

Sugars were determined in duplicate according to AOAC methods (AOAC, 1960). The reduced copper was titrated with sodium thiosulfate as outlined under the Munson-Walker general method.

Data on the sugar content of the laminated and control disks is given in Tables 41 through 47. No significant differences were apparent between the laminated and control storage samples. The storage effects on the foods varied as outlined below:

Pineapple	The percent of non-reducing sugars for the disks stored at 100°F were lower than the disks analyzed at 0-months storage indicating that some of the non-reducing disaccharides might have been hydrolized.
Onions	The reasons for the fluctuations in sugar content of the stored samples was not apparent.
Cookies & Caramel	The storage period resulted in no significant changes in the sugar content of the disks.
Carrots	Data indicates that the samples stored at 100°F might have undergone hydrolysis of the non-reducing and degradation of the reducing sugars.
Strawberries	Values for percent sugar for the samples stored at 70°F and 100°F were significantly lowered indicating possible hydrolysis and degradation of the non-reducing and reducing sugars respectively.
Cabbage	As the storage temperature increased there appeared to be a progressively greater incidence of hydrolysis and degradation of the non-reducing and reducing sugar respectively.

5. Total Bacteria

Total bacteria were determined by the standard plate count method of the American Association of Cereal Chemists (1962).

Results of the microbiological examination of the onion, caramel, carrots and cabbage disks are given in Tables 48 through 51. For the pineapple, cookie and strawberry disks the standard plate count per gram at 0 to 3 months storage was less than 300 and were consequently not reported in the tables.

Onion and Caramel

The standard plate count per gram for both the laminated and control disks at 0-months storage was less than 300. The bacteria that were

there, however, apparently multiplied during the storage period except at 100°F storage temperature. The significantly larger bacterial population on the laminated disks were expected because of the additional handling during manufacturing. The 100°F storage temperature was apparently detrimental to bacterial growth.

Carrots and Cabbage

The standard plate counts per gram for both the laminated and control disks were all low. There did not appear to be any significant differences between the control and laminated samples.

6. Degree of Laminate Separation

The degree of laminate separation was determined on the laminated disks. The laminates were separated with the aid of a knife. Those laminates that broke were noted as well as those that did not break. The number of laminates that did not break were averaged and this average was then divided by the number of laminates per disk and the result was expressed as a percent.

In Table 52 the values for the degree of laminate separation for all of the foods are noted. Laminated cabbage disks were the only ones not significantly affected by the storage period, particularly the 100°F storage period. For all of the other foods modifications are needed in order to insure more adequate separation of the laminates after storage.

7. Hardness

The procedures for evaluating hardness were discussed earlier in the "Experimental" section under "Evaluation Procedures". There was no change in the degree of hardness during the storage period. The control disks were rated extremely hard and the laminates were rated moderately hard before and after storage.

8. Rehydratability

Procedures for evaluating rehydratability were discussed earlier in the "Experimental" section under "Evaluation Procedures".

Data for all of the foods except cookies and caramel are given in Tables 53 through 62. Being thinner, all of the individual laminates rehydrated quicker than the control disks after storage as they did before storage. The storage effects on the foods varied as outlined below:

Pineapple The control disks possessed better rehydrating properties in 170°F water after storage than before storage. The rehydratability of the control disks in 78°F water did not appear to be affected by the storage conditions. The control disks stored at 100°F seemed to

have poorer rehydrating properties in 170°F water than the disks stored at the other temperatures.

While the control disks appeared to have better rehydrating properties in 170°F water after storage than before, the reverse seemed to be true for the laminates rehydrated in water at both 78°F and 170°F (Table 53). As was true with the control disks those laminates stored (together as a laminated disk during storage) at 100°F rehydrated slower in 170°F water than the laminates stored at lower temperatures.

Onion The control disks possessed better rehydrating properties in 78°F water before storage than after storage. The rehydratability of the control disks in 170°F water does not appear to be affected by any of the storage temperatures except 100°F.

The rehydratability properties of the laminates patterned themselves after the control disks in that the rate of rehydration was slower after storage than before storage (Tables 55 and 56). Those laminates stored (together as a laminated disk during storage) at 100°F rehydrated slower in 170°F water than the laminates stored at lower temperatures.

Carrots Control disks before and after storage appeared to have about the same rehydration properties in 78°F water (Table 57). In 170°F water the storage period seemed to cause the carrots to rehydrate slower. Control disks stored at 100°F seemed to have poorer rehydration properties in 78°F water. In 170°F water on the other hand 70°F and 100°F samples rehydrated better than the other samples for some unknown reason.

The laminates rehydrated better before storage than after in 78°F water (Table 58). No other significant results were noticed.

Strawberries The control disks were extremely hard to rehydrate (Table 59). Percent rehydration before and after storage appeared to be about the same. In 170°F water 70°F and 100°F samples rehydrated less than the other samples stored at lower temperatures. Laminates rehydrated better before than after storage (Table 60). Furthermore, samples stored at 100°F and 70°F took longer to rehydrate than the other samples stored at lower temperatures.

Cabbage Percent rehydration in 78°F before and after storage appeared to be about the same for the control disks (Table 61). In 78°F water, however, the samples at 0-months storage rehydrated better than the stored samples, and the difference became even more evident as the storage temperature increased.

In 170°F water the rehydration of the laminates was so fast that there was little or no difference between the samples (Table 62). Rehydration of the samples in 78°F water appeared to vary with temperature with the 0-months sample rehydrating in about the same time as the stored samples.

IV. RESULTS AND DISCUSSION, PHASE II

As outlined in the "Introduction" the research effort for Phase II of the contract was divided into two aspects:

- To compensate for deficiencies noted in the lamination mechanism developed for compacted freeze dried carrot and strawberry bars in Phase I and to develop and apply the laminating mechanism to compacted casserole (rice-beef-pea), non-fat milk solids and dehydrated meat bars.

- To identify levels of pressure, humidity and oxygen concentration to be avoided during storage of compacted rice-beef-pea, casserole, non-fat milk solids, dehydrated meat and freeze dried carrot and strawberry bars.

A. Refinement and Development of the Laminating Mechanism

The results of the storage study for Phase I revealed among other things that the laminating mechanism needed modifications so that it would hold up under storage. Consequently, to hold the laminates together a combination of pressure and "adhesive" in the form of Myverol 1800 was used.

Myverol 1800 was selected because it was easily and effectively applied (grains of Myverol 1800 - approximately 0.1 gm - were sprinkled on each laminate before pushing the laminate into the holding die). It was also stable at the storage temperatures used, met the caloric requirements, and there was little or no visible penetration of the Myverol 1800 into the laminates. The amount of pressure used varied with the food: rice-beef-pea casserole -- 100 psi/60 sec., freeze dried strawberries -- 500 psi/ 5 sec., freeze dried carrots -- 750 psi/30 sec. The laminating mechanism was not applicable to the dehydrated meat and non-fat milk solids bars.

Another area of refinement, as spelled out in the Statement of Work, was to permit separation of the laminates from the laminated food shape by biting them off as well as biting through them. In applying the laminating mechanisms to the foods, the thickness of the laminates influenced both. Consequently, the thickness and character of the laminates was first adjusted such that the "incisors" were allowed to grip each laminate individually and separate it from the laminated bar. Next the hardness of the laminates was adjusted by changing the compression level, altering the moisture content of the food and/or the amount of the material used to make the laminates.

Seven or eight laminates per bar seemed to be of sufficient number to demonstrate the general applicability of a laminating system to each of the three foods tested thus far.

1. Rice-Beef-Pea Casserole

Various materials and combinations of materials were experimented with in an attempt to develop a satisfactory casserole type bar: vegetable and beef stew (Armour), rice and chicken dinner (Armour), chicken stew (Armour), Rice-A-Roni (Golden Grain), potato-beef-pea combination, and rice-beef-pea combination. Of these, the rice-beef-pea combination resulted in the best compacted bar.

Compression tests showed that the pre-cooked rice held together best when its moisture content was increased from 10 to 16%. The beef and pea components were prepared so as to have as high a density as possible prior to compression: the beef was completely infiltrated with Myverol 1800, and the peas were air dried. Preliminary experiments indicated that the following proportion of rice, beef, pea and flavoring would result in a bar that would best fit the objectives of the experiment:

Pre-conditioned pre-cooked rice - 55%
Myverol 1800 infiltrated freeze dried cooked beef - 25%
Dried cooked frozen peas - 16%
Flavorings (Salt, MSG) - 4%

Compressing 2.5 grams of the above rice-beef-pea combination at 4000 psi/60 sec. resulted in a laminate measuring 2.1mm x 12.8mm x 44.8mm (thickness, width, length) and of sufficient thickness for gripping with the incisors. The laminate was slightly hard with excellent cohesiveness.

When 21.6 grams of the combination were compressed at 400 psi/60 sec. the resulting bar was moderately hard. Compression studies were then performed to see if a higher density and hardness rating could be obtained with the following results:

Press & Dwell	Density After Compression (gm/cc)	Hardness
2000/60	0.956	slight
3000/60	1.029	moderate
4000/60	1.155	moderate
5000/60	1.155	moderate

Increasing the compression level above 4000 psi did not increase the density or hardness rating. Consequently, the 4000 psi level was selected as the proper level to make the laminates and control bars. The specifications for the laminated and control bars are noted in Tables 63 and 64 respectively.

2. Freeze Dried Strawberries

Freeze-dried strawberries at 1.50% moisture content were too dry to be formed into a cohesive laminate. After pre-conditioning to 4.14% moisture content, satisfactory laminates could be made. Comparable results were found in Phase I.

Experimental 2 gram laminates and 14 gram control bars were made at different compression levels. The results are best described in terms of hardness as noted below:

Compression Level (psi)	Control Bar	Laminates
2500	moderately	slightly
3000	very hard	moderately
4000	extremely	moderately

At the 2500 psi level the laminates were not significantly softer than the control bar -- both were bitable. This was not true at the other two levels. To avoid the adverse effects of unnecessarily high compression levels, the 3000 psi level was selected as the desired level to make the laminates and control bars. The specifications for the laminated and control bars are noted in Tables 63 and 64, respectively.

3. Freeze Dried Carrots

At a moisture content of 0.42 percent, the freeze-dried carrots could not be compressed into cohesive laminates. By increasing the moisture content to 6.60%, satisfactory laminates could be made.

Moisture Content (% Dry Basis)	Cohesiveness	Hardness
0.42	Poor	Slight
3.50	Fair	Slight
4.74	Good	Slight
6.60	Good	Moderate

The moisture content was increased from the 4.33% reported in Phase I in an attempt to produce a more satisfactory laminated bar. Another improvement over the laminated bar reported in Phase I is the substitution of Myverol 1800 for the corn syrup as the laminating material.

When 2 grams of pre-conditioned freeze-dried carrots were compressed at 4000 psi/60 sec. a laminate 3.9mm x 13.3mm x 45.3mm resulted. The laminate was moderately hard with good cohesiveness.

To make an unlaminated bar, 17 grams of pre-conditioned freeze-dried carrots were compressed at 4000 psi/60 sec. The resulting bar was 13.3mmx32.6mmx45.3mm with moderate hardness and good cohesiveness.

The hardness of the laminates and of the control bar was the same. Furthermore, bite sized portions could be removed from the unlaminated bar just as easily as from a laminated bar. (Biting action perpendicular to the direction of compression).

In Phase I unlaminated freeze-dried carrot bars were found to be unbitable, yet in Phase II they are considered bitable. The answer to the dilemma lies in the orientation of the biting action in relation to the direction of the compression required to make the bar. In Phase I the biting action was parallel rather than perpendicular to the direction of compression.

Seventeen grams of pre-conditioned freeze-dried carrots were compressed in the 1 1/4 inch x 1 3/4 inch die at 4000 psi/60 sec. The resulting bar (control) was 13.2mm x 32.8mm x 45.3mm, or almost exactly the same dimension as the previously mentioned unlaminated bar. Biting through the 13.3mm dimensions was impossible, yet the same dimension for the unlaminated bar was bitable. This, then, is the new mechanism termed compression orientation.

Experimental 2 gram laminates were made at different compression levels. The results are noted below in terms of hardness:

Compression Level (psi)	Laminates
2000	Slight
3000	Moderate
4000	Moderate
5000	Moderate

To avoid the adverse effects of unnecessarily high compression levels, the 3000 psi level was selected as the proper level for further experiments.

After a considerable number of compression trials, it was found that eight 2.1 gm laminates compressed at the 3000 psi level (60 sec. dwell time) and made into a laminated bar came closest to the 32.8mm dimension of the control bar. Using 16.8 gm (8 x 2.1 gm/laminate) of the carrots to make the compression orientated and control bars also resulted in approximately the same dimensions as those for the laminated bar.

The specifications for the laminated bars are found in Table 63 The compression orientated and control bars' specifications are noted in Table 64.

Unsuccessful attempts were made to form unbiteable dehydrated meat control disks as described below:

Twenty-five grams of the freeze-dried ground beef (lipid content 28.49% of moisture free oven solids) were compressed at 3750 psi for 60 seconds. (Higher compression levels only resulted in more fat extruding from the meat). The disk thickness was 11.1mm. The disk was only slightly hard. Consequently, work with the pre-cooked, freeze-dried ground beef was discontinued.

- Council Brand of wafer sliced dried beef (smoked and dried cured beef) was purchased from a local store. As the meat was still too moist (5.01% moisture content) for compression purposes it was dried to 0.04% moisture content in an oven at 130°F for 3 hours. A sample weighing 40 gm was compressed at 5000 psi for 60 seconds. The thickness of the disk was 13.0mm. The disk was only moderately hard; the disk was bitable and therefore work with the wafer sliced dried beef was discontinued.

- Armour brand Star Lite freeze-dried beef steak and pork chops were purchased from a local store. The meat was cut up into little pieces and 30 gm samples of each were compressed at 5000 psi for 60 seconds. The disk thicknesses were 11.3mm and 12.1mm for the beef steaks and pork chops respectively. The disks were characterized as only moderately hard. Therefore the experiments on the freeze-dried beef steaks and pork chops were discontinued.

No difficulties were encountered in making unbiteable and slow rehydrating non-fat milk solids control bars:

Press & Dwell (psi/sec)	500/60, die inverted, 500/60
Bar weight (gm)	17.5
Bar Dimensions (mm)	13.0 x 32.7 x 45.6
Bar Cohesiveness	good - bar density uniform
Rehydratability	after 30 minutes in 170°F water volume unrehydrated material was 7.0mm x 28.5mm x 39.5mm.

The laminating mechanism was not found to be applicable to the non-fat milk solids, however. A satisfactory laminate could not be made which would rehydrate yet be sufficiently cohesive:

Press & Dwell (psi/sec)	500/30	250/30	100/30
Laminate wt. (gm)	2.5	2.0	2.5
Laminate cohesiveness	good	fair	poor
Rehydrateability (min)	30	30	-

Consequently, no further work was done with the non-fat milk solids.

B. Storage Study

The storage study as outlined in the Statement of Work centers around these questions:

Question One

How do the laminated samples compare physically, chemically and microbiologically with the control samples after both have been stored for 3 months at 100°F and cycling 0 to 40°F?

Question Two

What is the effect of sustained pressure, humidity and gaseous oxygen for 3 months at 100°F and cycling 0 to 40°F on the physical properties of the laminating mechanism and on the organoleptic, chemical and microbiological properties?

The storage temperatures are self-descriptive. Information on the other environmental conditions is given below:

- Pressure

  To determine how much physical protection a package should give the laminated food, a sustained pressure of 50 psi was applied throughout the storage period. Pressure was applied to the food bars while they were in one of two positions: upright (pressure exerted perpendicular to the flat surface of the laminates) and side (pressure exerted parallel to laminates.) After calculating the top surface area of the bars they were placed in a laminated bag, the bag was sealed and placed between metal plates. Knockout springs (deflection-pressure figures were known) at each corner were depressed a required distance to produce the 50 psi pressure (Figure 6).

- Humidity

  What protection, if any, the compacted food bars should receive from moisture, or lack of moisture, was determined by exposing them to magnesium perchlorate (0% R.H. at 70°C) and a saturated solution of sodium chloride (75% R.H. at 70°C). Wink jars were used for this experiment.

- Gaseous Oxygen

  Whether or not the food bars should be packaged in an inert atmosphere, and if so, to what degree, was determined by canning the foods under the following conditions: seal in ambient air, evacuate-purge with nitrogen once and seal, evacuate - purge with nitrogen twice and seal.

After briefly mentioning the evaluation procedures used in the storage study the results are discussed.

C. Evaluation Procedures

The effects of the storage conditions on the samples was determined by evaluating their physical, organoleptic, chemical and microbiological properties.

1. Physical Properties

The procedures for evaluating hardness and rehydrateability were discussed earlier in the "Experimental" Section under "Evaluation Procedures".

The separability of the laminates was described according to whether they could be bitten off individually or not. If some laminates separated druing storage, this was noted under "Damage" in the tables.

2. Organoleptic Properties

a. Operation of Panel

At each storage temperature (100°F, cycling 0° to 40°F) there were groups of samples, each group receiving one of the following treatments: pressure, humidity, gaseous oxygen. The number of samples in each group was at a proper level for tasting in one sitting (6-8) except for the gaseous oxygen group (9-12). Consequently, this group was split in two and tasted over two sessions, making a total of 4 tasting sessions in all for each temperature. These tasting sessions were done in random fashion over the 4 day period required for each food.

Within each group were subgroups containing sets of samples. (The pressure and humidity groups each have two subgroups, while the gaseous oxygen group has three subgroups). At the most, each set consisted of four samples, two "softened" and two "unsoftened". One unsoftened sample was used as a labeled control. The other three samples (two "softened" - one "unsoftened") were coded. (Two softening mechanisms were tested for carrots, one each for casserole and strawberries.) The judges were not informed that one coded sample was always a duplicate of the labeled control. This testing procedure was adopted to detect any evidence of bias among the judges, either for or against the labeled control.

Using the ballot shown in Figure 7, five or six experienced panel members were asked to note (1) any flavor differences

and (2) their preference between the coded samples and the sample labeled "S". For calculation purposes, the difference and preference levels were numbered as indicated in Figure 7.

The food bars were prepared for the panel in such a manner that the physical difference between the "softened" and "unsoftened" bars was masked. Casserole bars were allowed to rehydrate in a slight excess of 170°F water which was drained off before serving the food to the panel. Strawberry bars were ground up in a mechanical grinder and then served to the panel.

b. Data Evaluation

Separate analyses were performed on the preference and difference data collected for each group. A statistical evaluation of the data was made on a computer (CDC 1604 A). Each separate analysis then was a problem for the computer. The layout of a typical problem is noted below (for the gaseous oxygen group in this case):

Oxygen Groups	Temp.	Sample Sets		Data for Tasters
N_2	0 to 40°	1	(Experimental	
		2	(Control).	
	100	1		
		2		
N_1	0 to 40°	1		
		2		
	100	1		
		2		
Air	0 to 40°	1		
		2		
	100	1		
		2		

The scores under each temperature for each subgroup were the result of a comparison with a new standard. Consequently, the results for the samples of each set can not be compared with their counterpart in another set, i.e., the score for sample 1, 0 to 40 temp., N_2 subgroup, cannot be compared with the score for sample 1, 100 temp., N_2 subgroup. What can be compared is the position of the sample containing the softening mechanism relative to the sample without the softening mechanism among each set of samples.

For convenience and economy, and existing program (BIMD 11) was used (Biomedical Computer Project, 1964). This program analyzed the data as a factorial experiment, thereby performing nearly all of the necessary arithmetic for the statistical analysis. By means of only a small amount of

additional arithmetic (done manually) the computer results were transformed to the desired form. The analysis of variance for the problem shown above involving six tasters is as follows:

Source of Variation	Degrees of Freedom
Sample	1
Interaction	5
Residual	60
Error	5
Total	71

3. Chemical Properties

A component in each food, susceptible to deterioration over storage, was selected for evaluation by a suitable chemical test. The foods and the tests they were submitted to are noted below:

a. Casserole (Rice-Beef-Pea Combination) - Thiobarbituric Acid

The TBA method of Tarladgis et al (1960) was used to determine whether there were any differences in the degree of oxidation of the lipids in the casserole bars with and without the softening mechanisms over storage. Comparisons were also made between the samples with the softening mechanisms stored under the various environmental conditions.

b. Freeze Dried Strawberries - Ascorbic Acid

To ascertain the differences in the loss of vitamin C in the strawberry bars with and without the softening mechanism over storage, the ascorbic acid method of Loeffler and Ponting (1942) was used. Comparisons were also made between the samples with the softening mechanisms stored under the various environmental conditions.

c. Freeze Dried Carrots - Beta Carotene

The chromatographic method of AOAC (1960) was used to evaluate the degree of oxidation of the beta-carotene in the carrot bars with and without the softening mechanism over storage. Comparisons were made between the samples with the softening mechanisms stored under the various environmental conditions.

4. Microbiological Properties.

Total bacteria was determined by the Standard Plate Count Method of the American Association of Cereal Chemists (1962). Comparisons were made between samples with and without the softening

mechanisms after storage as well as between the samples with the softening mechanisms stored under the various environmental conditions.

5. Headspace Gas Analysis

Headspace gas of the flexible pouches used in the pressure studies and the cans used in the gaseous oxygen studies was analyzed to provide, if possible, any additional information in evaluating the results of the storage studies.

A gas chromatograph (Varian-Wilkens Aerograph 1520), fitted with a thermal conductivity detector was used. Two columns were employed in the analysis. The first, located inside the instrument, was a 20" long x 1/4" diameter column containing silica gel. The second, located outside the instrument, was a 10' long x 1/4" diameter column containing 10% 5A & 90% BX molecular sieves.

The column inside the instrument was set at 100°C, the injector at 150°C and the detector at 150°C. Helium was passed through the column at 25 ml per minute. The sample size was 2 ml.

D. Storage Study Results

Each food will be discussed individually with a short summary noted first followed by detailed discussion of the results.

1. Casserole

For the aspects tested, the laminated bars were equal to or better than the samples without the laminating mechanism after storage for 3 months at 100°F or cycling 0 to 40°F (two cycles per week) in a can (evacuated-purged with nitrogen twice and sealed). The softening and easily rehydrating properties of the laminated bars were slightly better than the unlaminated bars.

In storing the laminated bars at temperatures of 100°F and cycling 0 to 40°F (two cycles per week) for 3 months the following packaging considerations should be met:

- Laminated bars do not have to be protected from sustained pressures of up to 50 psi.
- Laminated bars do not have to be protected from 0% relative humidity.
- Laminated bars must receive protection from relative humidities of 75% and higher.
- Laminated bars can be packaged under atmospheric conditions.

a. Comparison - Softened vs. Unsoftened

In Table 65 the results of tests to determine how the laminated and control samples compared after the storage period, are noted. The tests showed that the samples containing the laminating mechanism were equal to or better than the samples without the softening mechanism after storage for 3 months at 100°F or cycling 0 to 40°F in a can (evacuated-purged with nitrogen twice and sealed).

The softening and easily rehydrating properties of the laminated bars were slightly better than the control bars.

The shorter rehydration times for the sample stored at 100°F could be due in part to "bar relaxation" during storage, allowing the hot water to penetrate the bar faster.

The results of the TBA tests on samples stored at 100°F and cycling 0 to 40°F are remarkably similar. One explanation might be that the beef in the casserole is completely saturated with Myverol, effectively reducing contact of the beef lipids with oxygen (minimizing oxidation).

b. Physical Stability

The physical properties of the laminated samples as affected by sustained pressure, humidity and gaseous oxygen during the storage period are noted in Tables 66, 67 and 68. An evaluation of the hardness and appearance of the control samples is also noted in Tables 66 & 67 and was included for additional perspective.

Samples held in high humidity (as produced by saturated solutions of sodium chloride) throughout the storage period showed the only adverse effects of the environmental conditions studied - partial or complete laminate separation, crumbling, color loss (Tables 66 and 67). The chlorophyll of the peas was more susceptible to degradation, as evidenced by their color, at the 100°F storage temperature and high relative humidity. Except for some laminate separation during storage, the effects of sustained pressure, gaseous oxygen and low relative humidity (as produced by magnesium perchlorate) were nil. At 100°F storage all of the laminates were able to be orally separated with the incisors.

The rehydratability data found in Table 68 was rather inconclusive since the rehydration times were all so short (less than 3 min) and the differences between the samples relatively small.

c. Organoleptic Stability

In Tables 69 and 70, the results of the organoleptic tests to determine if sustained pressure, humidity, and gaseous oxygen over the storage period caused the laminating mechanism to adversely affect the taste of the samples are noted.

The data shows that the differences caused by the "softening" mechanism were no greater than the differences inherent in the "unsoftened" samples.

The preference analyses of variance for samples stored under the two relative humidities shows a significant "F" value for the samples (Table 70). The cause of the significance can be seen in Table 67 where the data shows higher scores for the "unsoftened" than the "softened" samples. Of the scores for the "softened" samples, the score causing the most concern is the one for samples stored at a combination of high relative humidity and high temperature (1.0 less acceptable), indicating that these storage conditions are to be avoided for samples containing the softening mechanism.

d. Chemical and Microbiological Stability

The chemical properties of the laminated samples as affected by sustained pressure, humidity and gaseous oxygen during the storage period are noted in Table 71 with supplementary data given in Tables 72 and 73 The microbiological data will also be discussed in this section.

The TBA values varied from 0.077 to 0.299 x 10^{-8} moles of malonaldehyde per bone dry sample, indicating a low level of rancidity, with the samples packed in the best way (purged with nitrogen twice) having a value of 0.222 for cycling 0 to 40°F and 100°F storage temperatures. Consequently, the chemical data did not reveal any large adverse effects of the various environmental conditions. Values for "pressure exerted on side" cycling 0 to 40°F, "air" cycling 0 to 40°F, and "air" at 100°F appear unreasonably high (first) and low (second, third) in light of the other TBA values.

A predictable trend was noted with the TBA values for the humidity subgroups; higher values were noted for the 75% R.H. than for 0% R.H., and for 100°F storage temperature than for cycling 0 to 40°F storage temperature; high temperatures and high relative humidities brought about more oxidation of the lipids than low temperatures and low relative humidities.

Moisture contents of the laminated samples stored 3 months at 0° R.H. and 75% R.H. are given in Table 68a. The expected results were obtained; samples stored at 0% R.H. lost moisture and those at 75% R.H. gained.

The headspace gas analysis of the bar containers stored for 3 months is given in Table 73 The effect of increasing the number of evacuate-purge with nitrogen cycles on the oxygen content of a No. 303 can is noted in the table.

It is interesting to note that with approximately equal headspace volumes, the headspaces of the samples stored under sustained pressure exerted on the face of the bars at 100°F, had higher CO_2 contents than where pressure was exerted on the sides of bars.

The microbiological analysis revealed that all of the laminated bars contained less than 300 bacteria per gram. There were no significant differences among the total bacteria loads of the laminated samples stored under sustained pressure, humidity and gaseous oxygen for 3 months at 100°F or cycling 0 to 40°F.

2. <u>Freeze-Dried Strawberries</u>

For the aspects tested, the laminated bars were equal to or better than the samples without the laminating mechanisms after storage for 3 months at 100°F or cycling 0 to 40°F (two cycles per week) in a can (evacuated-purged with nitrogen twice and sealed). Most significant was the dramatic improvement in the biteability and rehydratability of the freeze dried strawberry bars containing the laminating mechanism in comparison with those without the laminating mechanism.

In storing the laminated bars at cycling 0 to 40°F, (two cycles per week) for 3 months the following packaging considerations should be met:

- Laminated bars do not have to be protected from sustained pressures of up to 50 psi.
- Laminated bars do not have to be protected from 0% relative humidity.
- Laminated bars must receive protection from relative humidities of 75% and higher.
- Laminated bars can be packaged under atmospheric conditions.

At storage temperatures of 100°F for 3 months, the first consideration noted above will not be adequate; laminated bars stored at 100°F for 3 months must be protected from sustained pressures of 50 psi or more.

a. Comparison - Softened vs. Unsoftened

In Table 65, the results of tests to determine how the laminated and control samples compared after the storage period are noted. The tests showed that the samples containing the laminating mechanism were equal to or better than the samples without the softening mechanism after storage for 3 months at 100°F or cycling 0 to 40°F in a can (evacuated-purged with nitrogen twice and sealed). There were two notable exceptions to this (ascorbic acid 100°F and microbiological cycling 0 to 40°F) but these results appear unreasonably low and high, respectively, in light of the other results

Most significant was the dramatic improvement in the biteability and rehydratability of the bars containing the laminating mechanism in comparison with those without the laminating mechanism.

The ascorbic acid values were slightly lower for the laminated samples stored at cycling 0 to 40°F than for the control samples stored at the same temperature. More revealing was the adverse effect the 100°F storage temperature had on the control sample in comparison with the one stored at cycling 0 to 40°F.

A small difference existed between the microbiological values at 100°F storage temperature for the laminated and control samples with the former, receiving much more handling during lamination, surprisingly having the lower count. A much larger difference was found between the two storage temperatures.

b. Physical Stability

The physical properties of the laminated samples as affected by sustained pressure, humidity, and gaseous oxygen during the storage period are noted in Tables 74 and 75. An evaluation of the hardness and appearance of the control samples is also noted in Tables 74 and 75 and is included for additional perspective.

At the cycling 0 to 40°F storage temperature, the only condition producing a noticeable effect on the bars was the high humidity level where, as expected, the bar picked up moisture becoming dark red in color (Table 74). All of the laminates were able to be orally separated with the incisors.

Storage at 100°F, however, not only produced adverse effects due to high humidity but sustained pressure as well. The combination of high humidity and 100°F temperature served to make the bars stored under those conditions unedible. It was interesting to note that when stored at 0% R.H. the 100°F

temperature did not affect the color of the bars as it did at other storage conditions. The sustained pressure, whether exerted on the samples in an upright position or on their side (relative to the lamination) made the laminates more difficult to separate - a knife had to be used instead of being able to bite them apart - but they were separable into bite sized portions.

The results of the rehydration tests were all essentially the same - the laminates were separated after 5 minutes and completely rehydrated and disintegrated after 30 minutes in the 170°F water. There was little or no difference between samples stored under the various environmental conditions.

c. Organoleptic Stability

In Tables 76 and 77, the results of the organoleptic tests to determine if sustained pressure, humidity and gaseous oxygen over the storage period caused the laminating mechanism to adversely affect the taste of the samples are noted - samples stored at the 75% R.H. were not tasted due to their inedibility. The data shows that the differences caused by the "softening" mechanism were no greater than the differences inherent in the "unsoftened" samples.

The preference analysis of variance for samples stored under the three levels of gaseous oxygen shows a significant "F" value for the samples (Table 77). The cause of the significance can be seen in Table 72 where the data shows higher scores for the "unsoftened" than for the "softened" samples. No one temperature - oxygen level combination appears to be responsible for the lower values of the "softened" samples except possibly the "Air" 100°F combination.

d. Chemical and Microbiological Stability

The chemical and microbiological properties of the laminated samples as affected by sustained pressure, humidity and gaseous oxygen during the storage period are noted in Tables 71 and 78, with supplementary data given in Tables 72 and 73. .

The ascorbic acid values varied from 0.001 to 0.459% per bone dry sample with the samples packaged in the best way (purged with N_2 twice) having a value of 0.419 and 0.094 for 0 to 40°F (cycling) and 100°F storage temperatures, respectively, particularly devastating was the 100°F storage temperature in combination with the high humidity (0.001%).

There appears to be a decrease in ascorbic acid content with increase in gaseous oxygen content of the container for both storage temperatures. The fact that higher values were recorded for other environmental conditions where the oxygen content of the container was similar (Table 73) overshadows this trend however.

Moisture contents of the laminated samples stored 3 months at 0% R.H. lost moisture and those at 75% R.H. gained, with a greater increase noted for the samples at 100°F than cycling 0 to 40°F.

The headspace gas analysis of the bar containers stored for 3 months is given in Table 73. The effect of increasing the number of evacuat-purge with nitrogen cycles on the oxygen content of a No. 303 can is noted in the table.

As with the casserole bars, it was interesting to note that with approximately equal headspace volumes, the headspaces of the samples stored under sustained pressure exerted on the face of the bars at 100°F had higher CO_2 contents than where pressure was exerted on the sides of the bars.

The microbiological data for laminated bars stored for 3 months is found in Table 78. The standard plate counts varied from less than 3000 to 10,200 per gram, with the samples packaged in the best way (purged with nitrogen twice) having a value of 10,200 and 4,7000 for cycle 0 to 40°F and 100°F respectively - the former sample must have been subjected to an unusual source of contamination in light of the other results.

The most significant result was the effect of the 100°F storage temperature on the microorganisms; lower plate counts were recorded for samples stored at 100°F than cycling 0 to 40°F temperatures. Rather peculiar are the results for the humidity subgroups where the higher values are noted for the samples stored at 0% R.H. than for those at 75%.

3. Freeze Dried Carrots

The softened bars were equal to or better than the samples without the softening mechanism after storage for 3 months at 100°F cycling 0 to 40°F (two cycles per week) in a can (evacuated - purged with nitrogen twice and sealed). Most significant was the dramatic improvement in the biteability and rehydratability of the freeze dried carrot bars containing the softening mechanism with comparison with those without the softening mechanism.

In storing the laminated and compression orientated bars at 100°F and cycling 0 to 40°F (two cycles per week) for 3 months the following packaging considerations should be met:

	Laminated Bars		Compression Orientated Bars	
	0 to 40°F	100°F	0 to 40°F	100°F
Bars have to be protected from sustained pressures of 50 psi or more	Yes	Yes	Yes	Yes
Bars have to be protected from 0% relative humidity	Yes	Yes	No	Yes
Bars have to be protected from 75% relative humidity	No	Yes	No	Yes
Bars have to be protected from atmospheric oxygen	No	Yes	No	Yes

a. Comparison Softened vs. Unsoftened

In Table 65 the test results comparing the laminated control and compression orientated samples are given. Samples containing the laminating and compression orientation mechanism were equal to or better than the samples without the softening mechanism after storage for 3 months at 100°F or cycling 0 to 40°F in a can (evacuated - purged with nitrogen twice and sealed).

The compression orientated and laminated bars were bitable whereas the control bar wasn't.

The rehydration properties of the softened samples were better than the control samples after storage at 0 to 40°F cycling. At 100°F storage all the samples rehydrated in approximately the same time.

The shorter rehydration times for the samples stored at 100°F is probably due to "bar relaxation" during storage, allowing the hot water to penetrate the bar faster. The compression orientated sample was not affected due apparently to the manner of compression.

For all practical purposes the between sample variation at each storage temperature for the beta carotene values is of little consequence. The loss of carotene in the samples stored at 100°F should be noted, however.

The results of the microbiological examination on samples stored at 0 to 40°F cycling are remarkably similar considering the fact that the laminated sample had a lot more opportunity for contamination than the others. A storage of 100°F for 3 months apparently had a detrimental effect on bacteria present in the samples.

b. Functional Stability

The functional properties of the softened samples as affected by sustained pressure, humidity and gaseous oxygen during the storage period are noted in Tables 79, 80 and 81. An evaluation of the hardness and appearance of the control samples is also noted in Table 79, and is included for additional perspective.

The laminates were all separable regardless of storage temperature. Furthermore, there was no laminate separation during storage.

The destruction of the color (beta carotene) when exposed to oxygen, particularly at 100°F storage was clearly shown for all three types of bars. The pressure subgroups appeared to accelerate the loss of color.

At the end of the storage period the compression oriented bars still retained their softened quality. A destructive effect was noticed at pressure exerted on face/110°F, and 75%/100°F storage conditions. Similar deliterious effects were noticed with the control disks.

Most of the rehydration data for the softened samples given in Tables 80 and 81 appeared to show evidence of considerable with in sample variation. Not so for the Pressure Subgroups stored at 100°F however where the rehydratability of the bars was considerably hindered.

c. Organoleptic Stability

In Tables 82 and 83 the results of the organoleptic tests to determine if sustained pressure, humidity, and gaseous oxygen over the storage period caused the softening mechanisms to adversely affect the taste of the samples are noted - sample stored at the 75% R.H. were not tasted due to their inedibility. The differences caused by the "softening" mechanism were no greater then the differences inherent in the "unsoftened" samples.

The preference analysis of variance for samples stored under the two relative humidities shows a significant "F" value for the interaction (Table 83.) The data in Table 82 pertaining to the above analysis of variance shows that the effect of R.H. varied with the sample in no consistent pattern.

d. Chemical and Microbiological Stability

The chemical properties of the softened samples as affected by sustained pressure, humidity and gaseous oxygen during the storage period are noted in Tables 71 with supplementary data given in Tables 73 and 84.

The beta carotene values varied from 2 to 1167 ppm (dry wt. basis) with the samples packaged in the best way (purged with N_2 twice) having values of 1075 and 1167 at 0 to 40°F (cycling) and 689 to 700 at 100°F. The data ties in fairly well with the "Appearance" data noted in Table 79. The devastating effect of the 100°F storage temperature on samples exposed to atmospheric concentrations of oxygen (Table 73) was well in evidence. There was some indication that the sorption of moisture (Table 84) under the 75% R.H. storage conditions helped to prevent oxidation of the beta carotene.

Moisture contents of the softened samples stored 3 months at 0% R.H. lost moisture and those at 75% R.H. gained with a greater effect generally noted for the samples at 100°F then cycling 0 to 40°F as expected.

The headspace gas analysis of the bar containers stored for 3 months is given in Table 73. Increasing the number of evacuate-purge with nitrogen cycles on the oxygen content of a No. 303 can generally brought about a decrease in the oxygen content of the can.

The microbiological data for softened bars stored for 3 months is given in Tables 85 and 86. The standard plate counts varied from less than 3000 to 113,000 per gram, with the samples package in the best way (purged with nitrogen twice) having values of <3000 and 4700 for laminated bars and <3000 and 5200 for compression orientated bars.

The most significant result was the effect of the 100°F storage on the bacteria load; lower plate counts were recorded for samples stored at 100°F than cycling 0 to 40°F temperature.

No explanation is available to account for the high plate counts for laminated samples stored with pressure exerted on face.

Despite less handling with the compression orientated samples than the laminated samples there was no real noticeable difference between them except for the samples mentioned above.

SUMMARY

This is the final report of the work initiated under Quartermaster Corps Contract DA 19-129-AMC-44(N). The results will be summarized separately for Phase I and II.

A. Phase I

1. Five food groups each representing different types of hardness and resistance to rehydration were investigated:

    a. Dehydrated vegetables (freeze dried carrots, onions, air dried cabbage.)

    b. Dehydrated fruit (freeze dried strawberries, apples, pineapple, low moisture raisins).

    c. Dry cereal (Puffed Rice).

    d. Bakery product (non-leavened cookies).

    e. Confectionery (high cook caramel).

2. Five built-in mechanisms were experimented with: lamination, perforation, dry ice inclusion, pelletizing and use of chemicals.

3. Of the mechanisms studied, lamination (series of thin chips made to adequately adhere together by further compression or other means) proved to be the most effective way of softening and/or facilitating rehydration.

4. The laminating mechanism was incorporated into air dried cabbage, non-leavened cookies, high cook caramel, freeze dried carrot, strawberry, pineapple and onion disks. The seven foods were then submitted to a storage study.

5. Results of the storage study were:

    a. Sensory Evaluation

        (1) The taste panel could not detect any significant difference between the laminated and control disks.

        (2) Pineapple, strawberries, caramel and cookies were well accepted and the carrots, cabbage and onions were on the borderline between acceptable and unacceptable.

    b. Color and Sugars

    No significant differences between the control and laminated disks were noted.

c. Moisture

Slightly higher results were found for the laminated disks than for the control disks due to the nature of the laminating operation.

d. Total bacteria

Except for onions and carrots no significant differences were found between the laminated and control disks.

e. Degree of laminate separation

Except for the cabbage disks all of the foods experienced difficulty with laminate separation.

f. Hardness

The control disks were rated unbitable and the laminates were rated bitable.

g. Rehydrateability

Being thinner, all of the individual laminates rehydrated quicker than the control disks.

6. Major conclusions resulting from the storage study were:

a. The laminating mechanism is an effective means of softening and/or facilitating rehydration.

b. More work is needed to improve the laminating techniques with all foods except the cabbage disks.

B. Phase II

1. Three foods were investigated:

a. Freeze dried carrots and strawberries - laminating mechanism was refined and applied to bars for storage study.

b. Casserole - laminating mechanism was developed and applied to bars for storage study.

c. Dehydrated meat and nonfat milk solids - laminating mechanism was not found to be applicable.

(Laminating mechanism - grains of Myverol 1800 between the laminates plus pressure)

2. Conclusions and recommendations for the laminated casserole, freeze dried strawberry, and carrot bars were as given below:

a. The softened casserole, freeze dried strawberry and carrot bars were equal to or better than the samples without the softening mechanism after storage for 3 months at 100°F or cycling 0 to 40°F (two cycles per week) in a No. 303 can (evacuated-purged with nitrogen twice and sealed).

(1) The softening and easily rehydrating properties of the laminated casserole bars were slightly better than the control bars. (In spite of measures taken to develop a hard and/or slow-to-rehydrate food bar representing a casserole, a large difference between laminated and control bars was not possible to obtain.)

(2) Most significant was the dramatic improvement in the biteability and rehydratability of the freeze dried strawberry and carrot bars containing the softening mechanism in comparison with those without the softening mechanism.

b. For storing the laminated casserole and strawberry bars at 100°F and cycling 0 to 40°F (two cycles per week) for 3 months the following packaging considerations should be met:

	F/D Strawberries		Casserole	
	0,40°F	100°F	0,40°F	100°F
Bars have to be protected from sustained pressures of 50 psi	No	Yes	No	No
Bars have to be protected from 0% relative humidity	No	No	No	No
Bars have to be protected from 75% relative humidity and higher	Yes	Yes	Yes	Yes
Bars have to be protected from atmospheric oxygen	No	No	No	No

c. In storing the softened carrot bars at 100°F and cycling 0 to 40°F (two cycles per week) for 3 months the following packaging considerations should be met:

	Laminated Bars		Compression Orientated Bars	
	0,40°F	100°F	0,40°F	100°F
Bars have to be protected from sustained pressures of 50 psi or more	Yes	Yes	Yes	Yes
Bars have to be protected from 0% relative humidity	Yes	Yes	No	Yes
Bars have to be protected from 75% relative humidity	No	Yes	No	Yes
Bars have to be protected from atmospheric oxygen	No	Yes	No	Yes

V. REFERENCES CITED

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APPENDIX

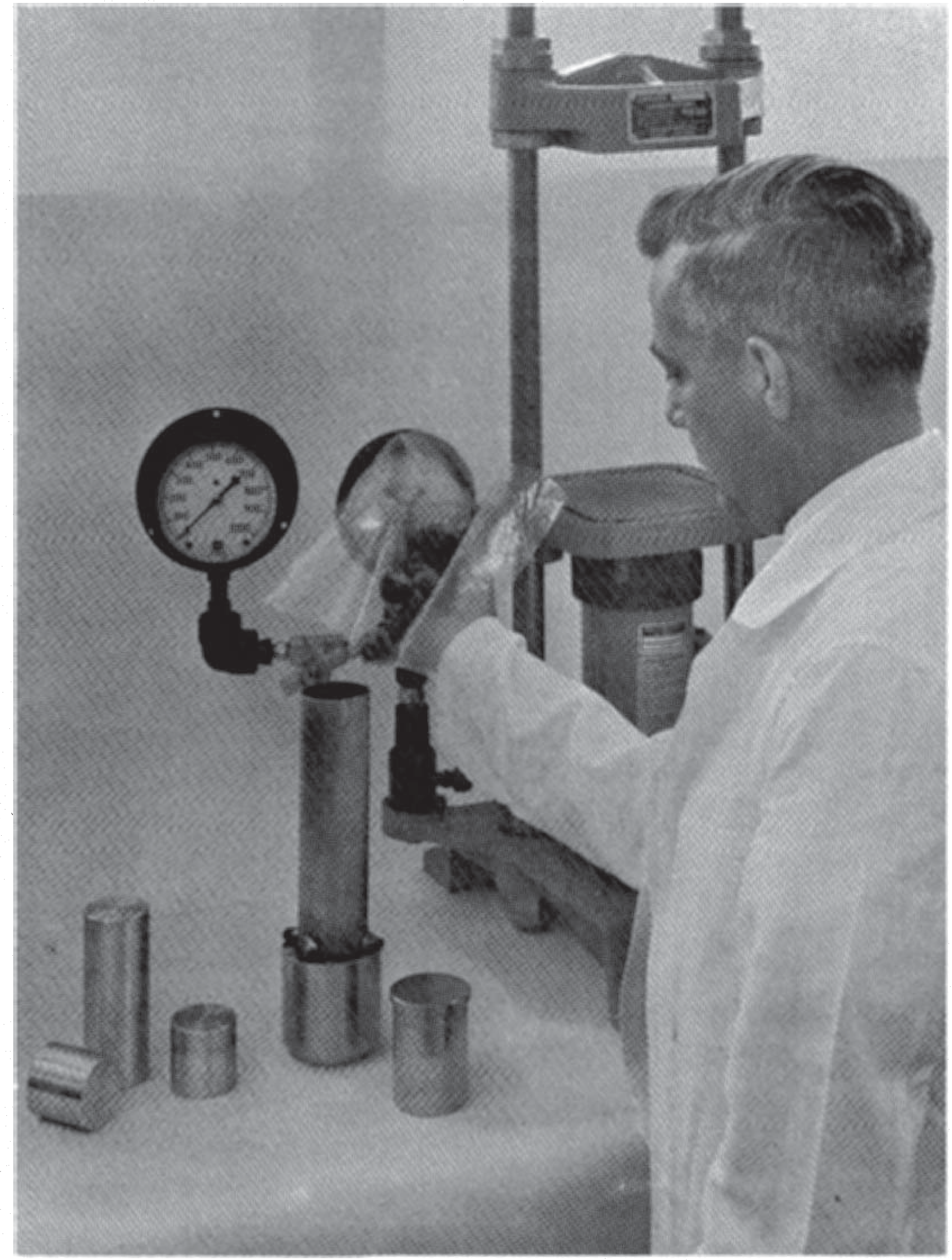

FIGURE 1 Auxiliary loading tube and three lengths of aluminum rod for compression of low density materials into the die in one continuous operation.

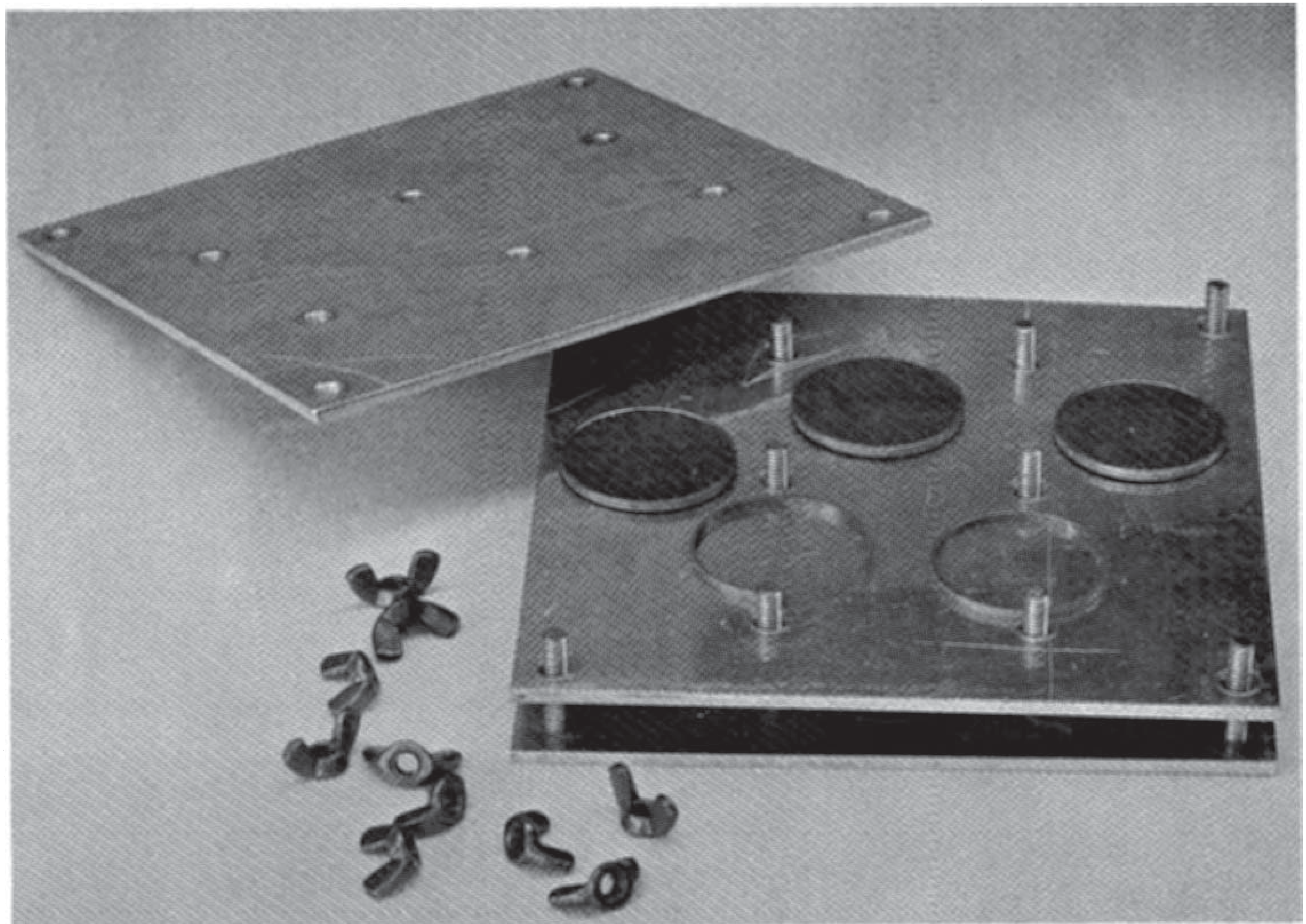

FIGURE 2 Molding apparatus showing 50.8 mm diameter by 3.2 mm thick rings containing non-leavened cookies.

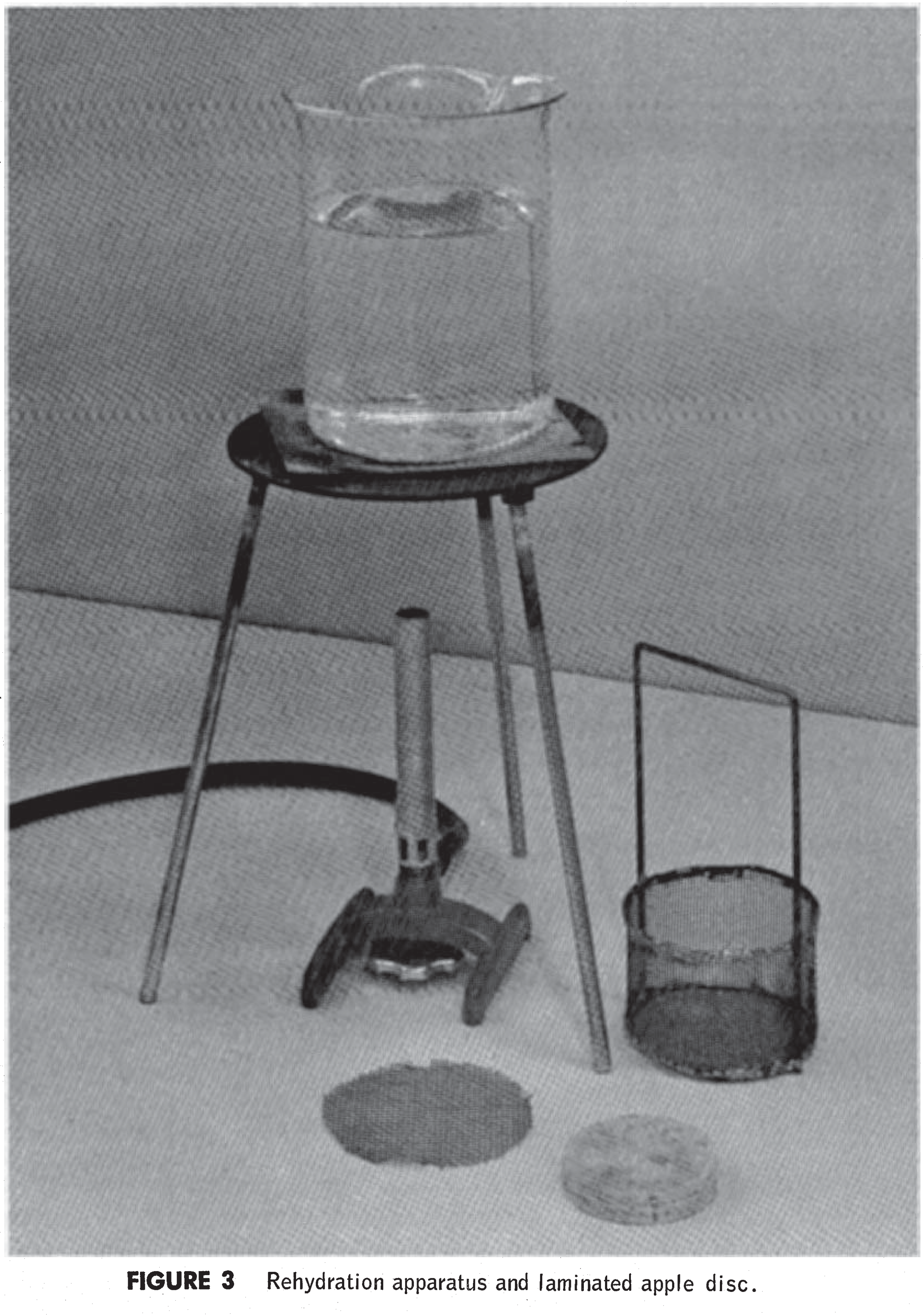

FIGURE 3 Rehydration apparatus and laminated apple disc.

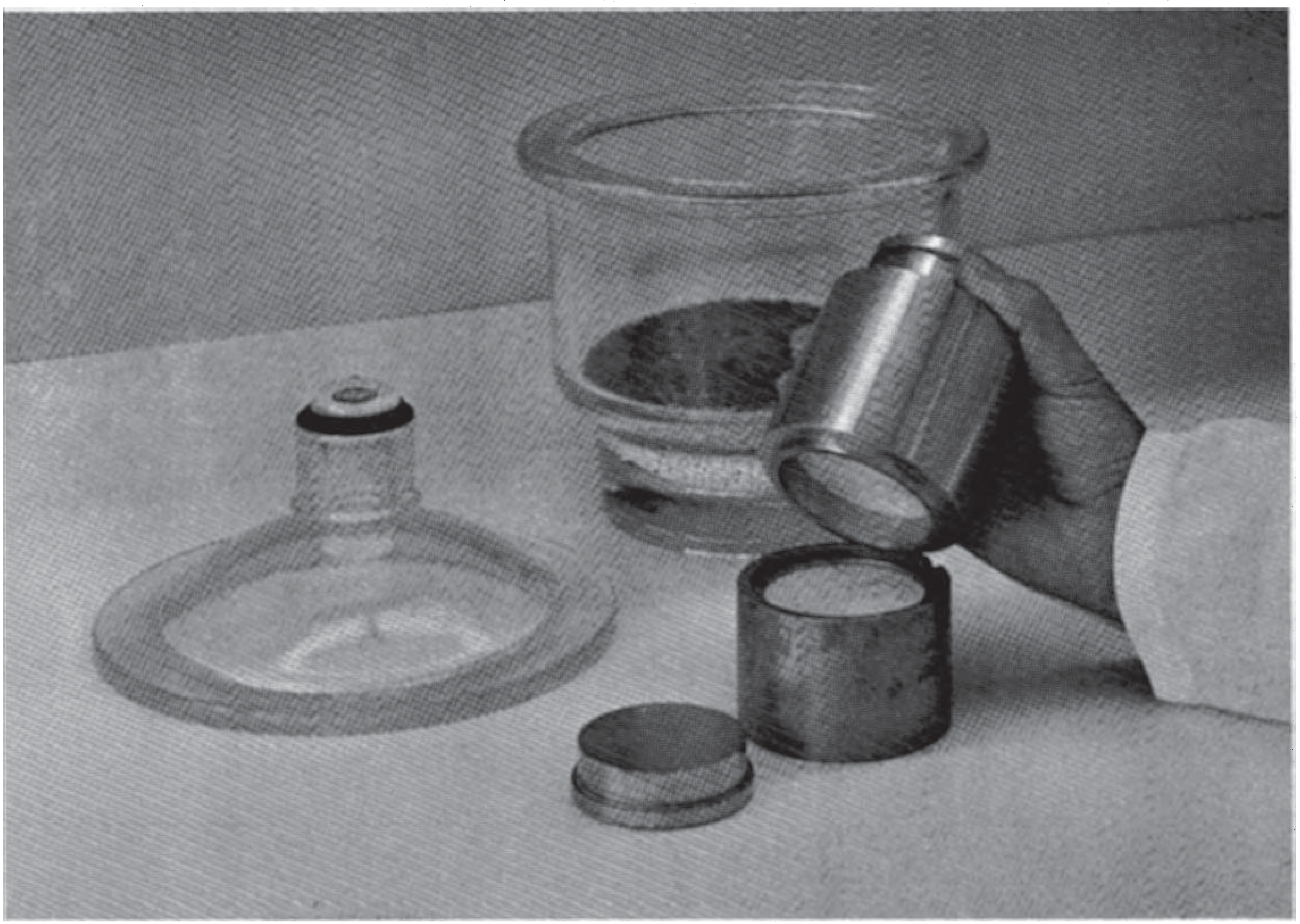

FIGURE 4 Accumulation of carrot laminates in holding die.

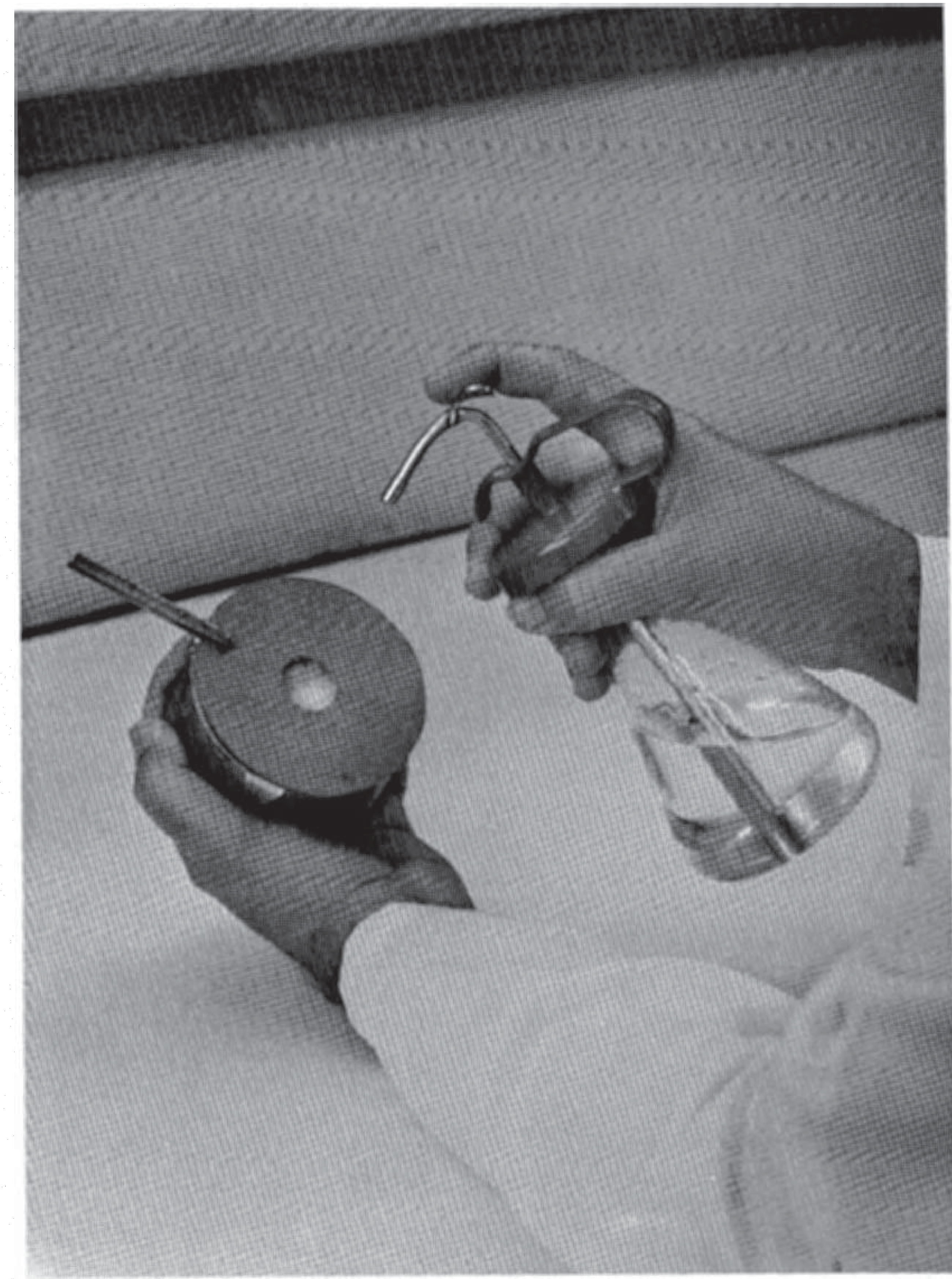

FIGURE 5 Illustration of procedure for using hand operated atomizer together with holding die and template for spraying apple laminates.

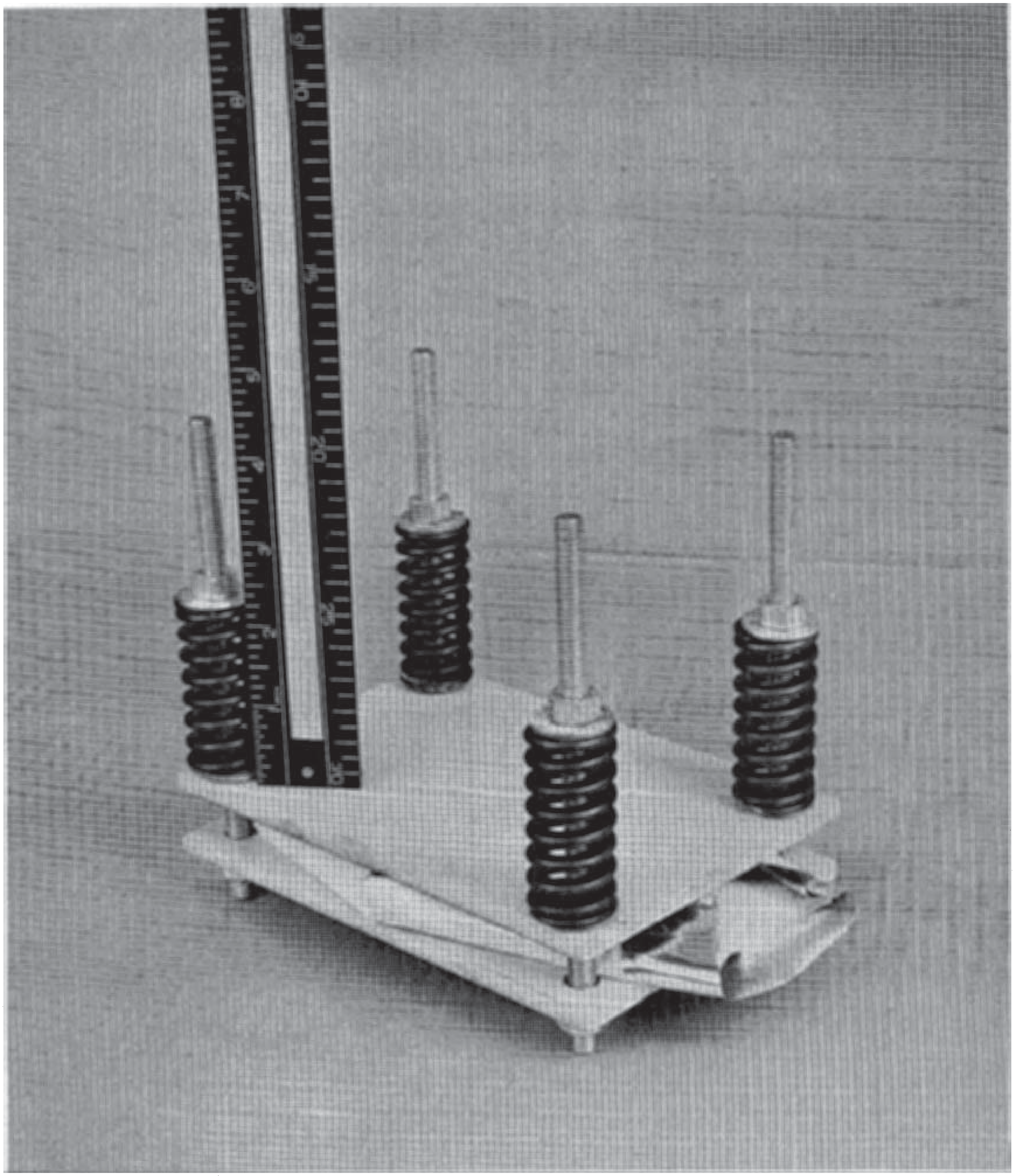

Figure 6 SUSTAINED PRESSURE TESTING APPARATUS

Name ______________ Product ______________

Compare the flavor of each of the numbered samples with that of the reference sample "S" and indicate the relative difference and relative acceptance from sample "S" by checking the appropriate squares. DO NOT MARK BETWEEN SQUARES!

SAMPLE ________

Difference		Preference	
Great	☐5	More Acceptable	☐3
Moderate	☐4	Comparable	☐2
Slight	☐3	Less Acceptable	☐1
Very slight	☐2		
No difference	☐1		

Comments

____

____

____

Figure 7

Taste Panel Ballot

TABLE 1

DESCRIPTIONS OF FOOD SAMPLES (AS PURCHASED)

Food Item	Type or Variety	Condition As Purchased	Brand and/or Distributor
Freeze Dried Carrots	Chatenay	Frozen	Local wholesaler; Dried, FMC
Low Moisture Raisins	California Seedless	Dried	Safeway Stores, Inc.; Dried, FMC
Cabbage Flakes	Copenhagen	Dried	General Foods, Inc.
Freeze Dried Apples	Newton Pippin	Frozen	Manteca Frozen Foods Manteca, California; Dried, FMC
Freeze Dried Strawberries	Shasta	Frozen	P.A. Mariani & Son, Inc; Dried, FMC
Freeze Dried Onions	Red	Fresh	Local wholesaler; Processed, dried, FMC
Freeze Dried Pineapple	Hawaiian Fancy	Fresh	Local wholesaler, Processed, Dried, FMC
Puffed Rice	-	Dried	Quaker Oats
Freeze Dried Cooked Ground Beef	-	Fresh	Local wholesaler, Processed, dried, FMC
Wafer Sliced Dried Beef	-	Dried	Council
Freeze Dried Cooked Beef	-	Dried	Armour Star Lite
Casserole			
Precooked Rice	Long Grain White	Cooked	General Foods, Inc.
Freeze Dried Peas	-	Frozen	Local Wholesaler, pro-
Freeze Dried Cooked Beef	-	Fresh	cessed, Dried, FMC
Non-Fat Milk Solids	-	Dried	Carnation Company

TABLE 2

CHARACTERISTICS OF CONTROL FOODS

Food	Weight (gm)	Pressure & Dwell (psi/sec)	Cohesiveness	Hardness	Dimension (mm)	Rehydration Data (%/min) 78°F	Rehydration Data (%/min) 170°F	Density (gm/cc)
Low Moisture Raisins (1.50% Moisture Content)	45.0	5000/30	Excellent	Very Hard	12.7x57.2	-	-	1.368
Freeze Dried Carrots (4.33% Moisture Content)	27.0	2500/90	Excellent	Extreme	12.7x57.6	16.9/5	35.5/5	0.720
Air Dried Cabbage Flakes (4.80% Moisture Content)	41.0	2500/20	Good	Extreme	12.7x57.7	9.5/5	100/4.5	1.235
Freeze Dried Apples (1.42% Moisture Content)	33.5	2500/90	Excellent	Extreme	12/7x57.7	11.9/5	20.3/5	0.933
Freeze Dried Strawberries (4.48% Moisture Content)	36.0	500/90	Excellent	Extreme	12.7x57.4	11.4/5	30.0/5	0.973
Freeze Dried Onions (1.97% Moisture Content)	35.5	5000/90	Good	Extreme	12.7x57.7	22.9/5	36.9/5	0.985
Freeze Dried Pineapple (2.77% Moisture Content)	38.5	1250/70	Excellent	Extreme	12.7x57.4	10/5	23.7/5	1.140
Puffed Rice (6.45% Moisture Content)	30.0	5000/75	Excellent	Extreme	12.7x57.9	100/30	100/2	0.723
High Cook Caramel	41.6	-	Excellent	Extreme	12.7x50.8	-	-	1.616
Non-Leavened Cookie	25.3	-	Excellent	Extreme	12.7x50.8	-	-	0.983

TABLE 3

CHARACTERISTICS OF INDIVIDUAL FOOD LAMINATES

Food	Weight (gm)	Pressure and Dwell (psi/sec)	Cohesiveness	Hardness	Dimensions (min)	Rehydration(100%) Time (min) 78°F	170°F	Density gm/cc
Low Moisture Raisins (1.50% Moisture Content)	11.5	5000/30	Excellent	Moderate	3.4x57.3	-	-	1.315
Freeze Dried Carrots (4.33% Moisture Content)	5.0	2500/60	Excellent	Moderate	2.6x58.2	10.0	1.5	0.558
Air Dried Cabbage (4.80% Moisture Content)	6.2	2500/60	Excellent	Moderate	1.9x57.7	14.5	0.5	1.149
Freeze Dried Apples (1.42% Moisture Content)	5.25	2500/60	Excellent	Moderate	2.2x57.8	15.0	3.0	0.784
Freeze Dried Strawberries (4.48% Moisture Content)	4.3	500/60	Excellent	Moderate	1.8x57.4	18.0	3.25	0.786
Freeze Dried Onions (1.97% Moisture Content)	6.0	3750/75	Good	Slight	2.7x58.0	9.0	0.5	0.772
Freeze Dried Pineapple (2.77% Moisture Content)	5.6	1250/60	Excellent	Moderate	2.3x57.6	18.0	1.0	0.860
Puffed Rice (6.45% Moisture Content)	4.0	5000/60	Excellent	Moderate	2.2x58.3	2.25	0.25	0.526
High Cook Caramel	7.6	-	Excellent	Moderate	2.4x50.8	-	-	1.560
Non-Leavened Cookie	5.5	-	Excellent	Moderate	3.2x50.8	-	-	0.846

TABLE 4

CHACTERISTICS OF LAMINATED FOODS

Food	Weight (gm)	Number of Laminates	Pressure & Dwell to Laminate (psi/sec)	Cohesiveness	Dimensions (min)	Density (gm/cc)	Misc.
Low Moisture Raisins (1.50% Moisture Content)	46.0	4	500/30	Excellent	12.7x57.2	1.382	Corn Starch (0.1 gm) brushed between the laminates
Freeze Dried Carrots (4.33% Moisture Content)	25.0	5	500/60	Excellent	12.7x57.7	0.648	25% solution of corn syrup sprayed between the laminates: 1st, 0.015 gm; 2nd, 0.015 gm; 3rd, 0.010 gm; 4th, 0.005 gm; 5th 0.000 gm.
Air Dried Cabbage (4.80% Moisture Content)	43.4	7	1250/90	Excellent	12.7x57.6	1.149	A 6.5% solution of thin boiling starch sprayed on cabbage before compression (2.5 to 3.5% by wt.)
Freeze Dried Apples (1.42% Moisture Content)	31.5	6	250/90	Excellent	12.7x57.4	0.886	Green marking between the laminates. Water sprayed between the laminates. 1st, 0.002 gm; 2nd, 0.002 gm; 3rd, 0.0015 gm; 4th, 0.0015 gm; 5th, 0.0004 gm; 6th, 0.000 gm.
Freeze Dried Strawberries (4.48% Moisture Content)	30.1	7	100/60	Excellent	12.7x57.4	0.852	Red marking between laminates. Laminating operation under normal room temperature and humidity.
Freeze Dried Onions (1.97% Moisture Content)	36.0	6	5000/75	Good	12.7x57.7	0.993	Green marking between the laminates. Water sprayed between the laminates: 1st, 0.0015 gm; 2nd, 0.0015 gm; 3rd, 0.0015 gm; 4th, 0.0004 gm; 5th, 0.0004 gm; 6th, 0.000 gm.
Freeze Dried Pineapple (2.77% Moisture Content)	33.6	6	525/30	Excellent	12.7x57.4	1.014	Yellow marking between the laminates Corn starch (<0.1 gm) brushed betweem the laminates.
Puffed Rice (6.45% Moisture Content)	24.0	6	1250/60	Excellent	12.7x57.9	0.601	0.024 gm of corn starch between each laminate.
High Cook Caramel	38.9	5	25/5	Excellent	12.7x50.8	1.511	See discussion under "Development of Laminating Mechanism".
Non-Leavened Cookie	22.6	4	-	Excellent	12.7x50.8	0.878	See discussion under "Development of Laminating Mechanism".

Table 5

COMPRESSION AND QUALITY EVALUATION: RESULTS OF RAISINS [1, 2]
TO ESTABLISH CRITICAL DIMENSIONS

grams ↓ \ Pressure* (psi) →	750	2500	5000
10	Thickness: 2.9 mm Hardness: moderate Density after compression:1.342 gm/cc	Thickness: 2.8 mm Hardness: moderate Density after compression:1.390 gm/cc	Thickness: 2.7 mm Hardness: moderate Density after compression:1.446 gm/cc
11	Thickness: 3.2 mm Hardness: moderate Density after compression:1.333 gm/cc	Thickness: 3.2 mm Hardness: moderate Density after compression:1.33 gm/cc	Thickness: 3.2 mm Hardness: moderate Density after compression:1.333 gm/cc
12	Thickness: 3.5 mm Hardness: moderate Density after compression:1.330 gm/cc	Thickness: 3.5 mm Hardness: moderate Density after compression:1.330 gm/cc	
14	Thickness: 3.9 mm Hardness: moderate Density after compression 1.330 gm/cc	Thickness: 3.9 mm Hardness: very hard Density after compression:1.392 gm/cc	

[1] Moisture content 1.50%

[2] All disks possessed excellent cohesivity

* Dwell: 90 seconds

Table 6

COMPRESSION AND QUALITY EVALUATION: RESULTS OF FREEZE-DRIED CARROT SLICES TO ESTABLISH CRITICAL DIMENSIONS

Pressure* (psi) → / grams ↓	750	1250	2500	5000
3	Thickness: 2.4 mm Hardness: slight Cohesiveness: good Density after compression: 0.468 gm/cc		Thickness: 1.9 mm Hardness: slight Cohesiveness: good Density after compression: 0.587 gm/cc	Thickness: 1.5 mm Hardness: slight Cohesiveness: excellent Density after compression: 0.749 gm/cc
6	Thickness: 4.7 mm Hardness: slight Cohesiveness: good Density after compression: 0.473 gm/cc	Thickness: 4.4 mm Hardness: slight Cohesiveness: good Density after compression: 0.511 gm/cc	Thickness: 3.2 mm Hardness: moderate Cohesiveness: excellent Density after compression: 0.702 gm/cc	Thickness: 2.7 mm Hardness: moderate Cohesiveness: excellent Density after compression: 0.835 gm/cc
9	Thickness: 7.3 mm Hardness: slight Cohesiveness: good Density after compression: 0.456 gm/cc	Thickness: 6.3 mm Hardness: moderate Cohesiveness: good Density after compression: 0.533 gm/cc	Thickness: 4.8 mm Hardness: very hard Cohesiveness: excellent Density after compression: 0.705 gm/cc	
12	Thickness: 9.5 mm Hardness: moderate Cohesiveness: good Density after compression: 0.467 gm/cc	Thickness: 8.4 mm Hardness: very hard Cohesiveness: good Density after compression: 0.526 gm/cc		

* Dwell: 60 seconds

Table 7

COMPRESSION AND QUALITY EVALUATION: RESULTS OF AIR-DRIED CABBAGE FLAKES TO ESTABLISH CRITICAL DIMENSIONS

Pressure* (psi) → / Grams ↓	750	1250	2500	3750	5000
4				Thickness: 1.6 mm Hardness: moderate Rehydration: 78°F- 100%, 5 min. 170°F--100%, 0.25 min. Density after com- pression: 0.937 gm/cc	Thickness: 1.5 mm Hardness: moderate Rehydration: 78°F- 100%, 6 min. 170°F- 100%, 0.25 min. Density after com- pression: 0.996 gm/cc
5	Thickness: 2.4 mm Hardness: slight Rehydration: 78°F- 100%, 3.75 Min. 170°F- 100%, 0.25 Min. Density after com- pression: 0.794 gm/cc	Thickness: 2.4 mm Hardness: moderate Rehydration: 78°F- 100%, 4.75 min. 170°F- 100%, 0.25 min Density after com- pression: 0.778 gm/cc	Thickness: 2.2 mm Hardness: moderate Rehydration: 78°F- 100%, 5.5 min. 170°F- 100%, 0.25 min Density after com- pression: 0.860 gm/cc	Thickness: 1.2 mm Hardness : very hard Rehydration: 78°F- 100%, 7.0 min. 170°F- 100%, 0.25 min. Density after com- pression: 0.136 gm/cc	Thickness: 1.7 mm Hardness: very hard Rehydration: 78°F- 100%, 7.5 min. 170°F--100%, 0.25 min. Density after com- pression: 1.129 gm/cc
10	Thickness: 4.8 mm Hardness : very hard Rehydration: 78°F- 100%, 6.0 min. 170°F- 100%, 0.5 min. Density after com- pression:0.765 gm/cc	Thickness: 4.3 mm Hardness: very hard Rehydration: 78°F-100%, 7.5 min 170°F-100%, 0.5 min. Density after com- pression: 0.868 gm/cc	Thickness: 3.7 mm Hardness: very hard Rehydration: 78°F- 100%, 23.0 min. 170°F- 100%, 0.50 min. Density after com- pression: 1.023 gm/cc		Thickness: 3.4 mm Hardness: extreme Rehydration: 78°F- 32.0%, 5 min. 170°F- 100%, 1 min. Density after com- pression: 1.113 gm/cc
15	Thickness: 7.4 mm Hardness : very hard Rehydration: 78°F- 100%, 8.5 min. 170°F- 100%, 1.0 min. Density after com- pression:0.749 gm/cc	Thickness: 6.0 Hardness: extreme Rehydration: 78°F- 41.9%, 5 min. 170°F- 100%, 1 min. Density after com- pression: 0.924 gm/cc	Thickness: 5.0 Hardness: extreme Rehydration: 78°F - 28.7%; 5 min. 170°F - 100%, 1.25 min. Density after com- pression: 1.139 gm/cc		
20	Thickness: 8.5 mm Hardness : extreme Rehydration: 78°F- 43.3%, 5 min. 170°F- 100%, 1.25 min Density after com- pression:0.891 gm/cc	Thickness: 7.3 mm Hardness: extreme Rehydration: 78°F- 37.7%, 5 min 170°F- 100%, 1.5 min Density after com- pression: 1.037 gm/cc	Thickness: 6.5 mm Hardness: extreme Rehydration: 78°F- 23.2%, 5 min. 170°F- 100%, 2 min. Density after com- pression: 1.165 gm/cc		

* Dwell, 60 seconds

Table 8

COMPRESSION AND QUALITY EVALUATION: RESULTS OF FREEZE-DRIED APPLE CUBES TO ESTABLISH CRITICAL DIMENSIONS

Pressure* (psi) → grams ↓	750	2500	3750	5000
4	Thickness: 2.2 mm Hardness: slight Rehydration: 78°F- 100%, 4.75 min. 170°F- 100%, 0.50 min. Density after compression: 0.683 bm/cc		Thickness: 1.8 mm Hardness: slight Rehydration: 78°F-100%, 11.50 min. 170°F-100%, 1.0 min.	
8	Thickness: 4.6 mm Hardness: slight Rehydration: 78°F- 48.1%, 5 min. 170°F-100%, 2.75 min. Density after compression: 0.66 gm/cc	Thickness: 3.5 mm Hardness: moderate Rehydration: 78°F- 40.3%, 5 min. 170°F-100%, 5.50 min. Density after compression: 0.871 gm/cc		Thickness: 2.8 mm Hardness: moderate Rehydration: 78°F- 33.0%, 5 min. 170°F-100%, 7.50 min. Density after compression: 1.0926 gm/cc
12	Thickness: 6.5 mm Hardness: moderate Rehydration: 78°F- 43.9%, 5 min. 170°F-100%, 7.25 min. Density after compression: 0.704 gm/cc	Thickness: 4.8 mm Hardness: moderate Rehydration: 78°F- 25.4%, 5 min. 170°F-100%, 12 min. Density after compression: 0.956 gm/cc		Thickness: 3.8 mm Hardness: very hard Rehydration: 78°F- 24.0%, 5 min. 170°F- 38.6%, 5 min. Density after compression: 1.212 gm/cc

* Dwell: 60 seconds

Table 9

COMPRESSION AND QUALITY EVALUATION: RESULTS OF FREEZE-DRIED STRAWBERRIES TO ESTABLISH CRITICAL DIMENSIONS

Pressure * (psi)→ gms ↓	250	500	750	1250	2500
4	Thickness: 1.8 mm Hardness: moderate Rehydration: 78°F-100%,16min. 170°F-100%,2.45min. Density after compression:0.811 gm/cc	Thickness: 1.7 mm Hardness: moderate Rehydration: 78°F-100%,16min. 170°F-100%,2.45min. Density after compression:0.909 gm/cc		Thickness: 1.5 mm Hardness: moderate Rehydration: 78°F-100%,19.50min. 170°F-100%,3min. Density after compression:1.034 gm/cc	Thickness: 1.4 mm Hardness: very hard Rehydration: 78°F-100%,22min. 170°F-100%,4min. Density after compression:1.030 gm/cc
5		Thickness: 2.1 mm Hardness: moderate Rehydration: 78°F-100%,26min. 170°F-100%,4.45min. Density after compression:0.920 gm/cc	Thickness: 2.0 mm Hardness: moderate Rehydration: 78°F-100%,28min. 170°F-100%,5.25min. Density after compression:0.966 gm/cc	Thickness: 1.9 mm Hardness: very hard Rehydration: 78°F-100%,34min. 170°F-100%,6min. Density after compression:0.938 gm/cc	
6	Thickness: 2.8 mm Hardness: very hard Rehydration: 78°F-100%,32min. 170°F-100%,7min. Density after compression:0.801 gm/cc	Thickness: 2.5 mm Hardness: very hard Rehydration: 78°F-100%,44min. 170°F-100%,9min. Density after compression:0.928 gm/cc			

*Dwell: 60 seconds

Table 10

COMPRESSION AND QUALITY EVALUATION: RESULTS OF FREEZE-DRIED ONIONS TO ESTABLISH CRITICAL DIMENSIONS

Pressure* (psi)→ grams ↓	750	2500	5000
4		Thickness: 2.1 mm Hardness: slight Rehydration 78°F - 100%, 2.0 min. 170°F - 100%, 0.25 min. Density after compression: 0.711 gm/cc	
6	Thickness: 3.5mm Hardness: slight Rehydration: 78°F - 100%, 0.75 min. 170°F - 100%, 0.25 min. Density after compression: 0.950 gm/cc	Thickness: 2.8 mm Hardness: slight Rehydration: 78°F - 100%, 5.0 min. 170°F - 100%, 0.5 min. Density after compression: 0.797 gm/cc	Thickness: 2.5 mm Hardness: slight Rehydration: 78°F - 100%, 17 min. 170°F - 100%, 0.5 min. Density after compression: 0.905 gm/cc
8	Thickness: 4.7 mm Hardness: slight Rehydration: 78°F - 100%, 2.0 min. 170°F - 100%, 0.25 min. Density after compression: 0.627 gm/cc	Thickness: 3.6 mm Hardness: slight Rehydration: 78°F - 100%, 10.5 min. 170°F - 100%, 0.5 min. Density after compression: 0.832 gm/cc	

*Dwell: 40 seconds

Table 11

COMPRESSION AND QUALITY EVALUATION: RESULTS OF FREEZE-DRIED PINEAPPLE TO ESTABLISH CRITICAL DIMENSIONS

Pressure (psi) → Grams ↓	525	1250
5	Thickness: 2.4 mm Hardness: slight Rehydration: 78°F - 100%, 9 min. 170°F - 100%, 0.75 min. Density after Compression: 0.799 gm/cc	Thickness: 2.1 mm Hardness: slight Rehydration: 78°F - 100%, 16 min. 170°F - 100%, 1.75 min. Density after Compression: 0.917 gm/cc
5.5	Thickness: 2.7 mm Hardness: slight Rehydration: 78°F - 100%, 15 min. 170°F - 100%. 0.75 min. Density after Compression: 0.782 gm/cc	Thickness: 2.3 mm Hardness: moderate Rehydration: 78°F - 100%, 17 min. 170°F - 100%, 1 min. Density after Compression: 0.934 gm/cc
6	Thickness: 2.8 mm Hardness: slight Rehydration: 78°F - 100%, 18 min. 170°F - 100%, 0.75 min. Density after Compression: 0.822 gm/cc	Thickness: 2.4 mm Hardness: moderate Rehydration: 78°F - 100%, 21 min. 170°F - 100%, 1.75 min. Density after Compression: 0.963 gm/cc

Table 12

COMPRESSION AND QUALITY EVALUATION: RESULTS OF PUFFED RICE TO ESTABLISH DIMENSIONS

Pressure* (Psi) → Grams ↓	750	2500	3750	5000
3		Thickness: 2.2 mm hardness: slight Rehydration: 78°F - 100%, 0.5 min. 170°F - 100%, 0.25min. Density after Compression:0.511 gm/cc	Thickness: 2.2 mm Hardness: slight Rehydration: 78°F - 100%, 1.25 min. 170°F - 100%, 0.25 min. Density after Compression:0.511 gm/cc	
4	Thickness: 3.5 mm Hardness: moderate Rehydration: 78°F - 100%, 0.25 min. 170°F - 100%, 0.25 min. Density after Compression:0.413 gm/cc			Thickness: 2.2 mm Hardness: moderate Rehydration: 78°F - 100%, 2.25 min. 170°F - 100%, 0.25 min. Density after Compression:0.681 gm/cc
5	Thickness: 4.1 mm Hardness: moderate Rehydration: 78°F - 100%, 0.25 min. 170°F - 100%, 0.25 min. Density after Compression:0.455 gm/cc			Thickness: 2.6 mm Hardness: very hard Rehydration: 78°F - 100%, 3.75 min. 170°F - 100%, 0.25 min. Density after Compression:0.723 gm/cc
6		Thickness: 4.5 min. Hardness: very hard Rehydration: 78°F - 100%, 0.75 min. 170°F - 100%, 0.25 min. Density after Compression:0.372 gm/cc		

* Dwell: 40 seconds

TABLE 13A

ANALYSIS OF VARIANCE OF SENSORY EVALUATION
OF FREEZE-DRIED PINEAPPLE FLAVOR

	Degrees of Freedom	Mean Square
Total	159	---
Between Treatments	7	---
Type of Disk	1	0.7562
Storage Temperature	3	53.4895**
Type of Disk x Storage Temperature	3	0.8729
Within Treatments	152	---
Replication	1	0.0057
Taster	9	16.3951**
Taster x Replication	9	0.7008
Taster x Treatment	63	1.5967**
Treats x Replication	7	0.3920
Treatments x Taster x Replication	63	0.5308

** Statistical Significance 1% level

TABLE 13B

ANALYSIS OF VARIANCE OF SENSORY EVALUATION
OF FREEZE-DRIED PINEAPPLE ODOR

	Degrees of Freedom	Mean Square
Total	159	---
Between Treatments	7	---
Type of Disk	1	1.6000
Storage Temperature	3	12.5083*
Type of Disk x Storage Temperature	3	0.7833
Within Treatments	152	---
Replication	1	0.0250
Taster	9	17.5556**
Taster x Replication	9	3.9000**
Taster x Treatment	63	1.2365**
Treatments x Replication	7	0.7536
Treatments x Taster x Replication	63	0.6603

** Statistical Significance 1% level
* " " 5% level

TABLE 14A

ANALYSIS OF VARIANCE OF SENSORY EVALUATION OF FREEZE-DRIED ONION FLAVOR

	Degrees of Freedom	Mean Square
Total	127	---
Between Treatments	7	---
Type of Disk	1	3.7813
Storage Temperature	3	5.2083
Type of Disk x Storage Temperature	3	1.4479
Within Treatments	120	---
Replication	1	0.2812
Taster	7	48.5360**
Taster x Replication	7	2.1027*
Taster x Treatments	49	3.2244**
Treatments x Replication	7	0.3526
Treatments x Taster x Replication	49	0.7863

** Statistical Significance 1% level
* " " 5% level

TABLE 14B

ANALYSIS OF VARIANCE OF SENSORY EVALUATION OF FREEZE-DRIED ONION ODOR

	Degrees of Freedom	Mean Square
Total	127	---
Between Treatments	7	---
Type of Disk	1	0.7813
Storage Temperature	3	0.9375
Type of Disk x Storage Temperature	3	0.1771
Within Treatments	120	---
Replication	1	2.5312**
Taster	7	15.3216**
Taster x Replication	7	0.5669
Taster x Treatments	49	0.6658**
Treatments x Replication	7	0.2277
Treatments x Taster x Replication	49	0.2838

** Statistical Significance 1% level

TABLE 15A

ANALYSIS OF VARIANCE OF SENSORY EVALUATION
OF COOKIE FLAVOR

	Degrees of Freedom	Mean Square
Total	159	---
Between Treatments	7	---
Type of Disk	1	6.4000
Storage Temperature	3	30.6833
Type of Disk x Storage Temperature	3	3.5833
Within Treatments	152	---
Replication	1	0.6000**
Taster	9	15.9278**
Taster x Replication	9	1.2944**
Taster x Treatments	63	2.1913**
Treatments x Replication	7	4.6857**
Treatments x Taster x Replication	63	0.0627

** Statistical Significance 1% level

TABLE 15B

ANALYSIS OF VARIANCE OF SENSORY EVALUATION
OF COOKIE ODOR

	Degrees of Freedom	Mean Square
Total	159	---
Between Treatments	7	---
Type of Disk	1	3.9062
Storage Temperature	3	6.4229
Type of Disk x Storage Temperature	3	2.7896
Within Treatments	152	---
Replication	1	0.7562
Taster	9	3.1146**
Taster x Replication	9	0.2424
Taster x Treatment	63	0.8416**
Treatments x Replication	7	0.4419
Treatments x Tasters x Replication	63	0.4201

** Statistical Significance 1% level

TABLE 16A

ANALYSIS OF VARIANCE OF SENSORY EVALUATION OF CARAMEL FLAVOR

	Degrees of Freedom	Mean Square
Total	159	---
Between Treatments	7	---
Type of Disk	1	0.2250*
Storage Temperature	3	0.2500**
Type of Disk x Storage Temperature	3	0.0083
Within Treatments	152	---
Replication	1	0.4000
Taster	9	6.2389**
Taster x Replication	9	1.0944**
Taster x Treatments	63	0.5595**
Treatments x Replications	7	0.3143
Treatments x Taster x Replication	63	0.2468

** Statistical Significance 1% level
* " " 5% level

TABLE 16B

ANALYSIS OF VARIANCE OF SENSORY EVALUATION OF CARAMEL ODOR

	Degrees of Freedom	Mean Square
Total	159	---
Between Treatments	7	---
Type of Disk	1	0.1000
Storage Temperature	3	0.1167
Type of Disk x Storage Temperature	3	0.4167
Within Treatments	152	---
Replication	1	2.5000*
Taster	9	15.6778**
Taster x Replication	9	2.2778**
Taster x Treatment	63	0.4333**
Treatments x Replication	7	0.2714**
Treatments x Taster x Replication	63	0.1603

** Statistical Significance 1% level

TABLE 17A

ANALYSIS OF VARIANCE OF SENSORY EVALUATION OF FRYEZE-DRIED CARROTS FLAVOR

	Degrees of Freedom	Mean Square
Total	143	---
Between Treatments	7	---
Type of Disk	1	0.0069
Storage Temperature	3	1.2292
Type of Disk x Storage Temperature	3	0.2292
Within Treatments	136	---
Replication	1	0.0069
Taster	8	46.1111**
Taster x Replication	8	1.9445*
Taster x Treatments	56	0.8492
Treatments x Replication	7	0.3403
Treatments x Taster x Replication	56	0.8492

** Statistical Significance 1% level
* " " 5% level

TABLE 17B

ANALYSIS OF VARIANCE OF SENSORY EVALUATION OF FREEZE-DRIED CARROT ODOR

	Degrees of Freedom	Mean Square
Total	143	---
Between Treatments	7	---
Type of Disk	1	0.1736
Storage Temperature	3	4.4144
Type of Disk x Storage Temperature	3	0.5255
Within Treatments	136	---
Replication	1	0.0625
Taster	8	22.0851**
Taster x Replication	8	1.5469
Taster x Treatments	56	1.0949
Treatments x Replication	7	0.3006
Treatments x Taster x Replication	56	0.7671

** Statistical Significance 1% level

TABLE 18A

ANALYSIS OF VARIANCE OF ORGANOLEPTIC EVALUATION OF FREEZE-DRIED STRAWBERRY FLAVOR

	Degrees of Freedom	Mean Square
Total	159	---
Between Treatments	7	---
Type of Disk	1	0.0563
Storage Temperature	3	41.1299**
Type of Disk x Storage Temperature	3	0.4062
Within Treatments	152	---
Replication	1	0.0563
Taster	9	22.2646**
Taster x Replication	9	0.4035
Taster x Treatment	63	1.1297**
Treatments x Replication	7	0.7277*
Treatments x Taster x Replication	63	0.2495

** Statistical Significance 1% level
* " " 5% level

TABLE 18B

ANALYSIS OF VARIANCE OF ORGANOLEPTIC EVALUATION OF FREEZE-DRIED STRAWBERRY ODOR

	Degrees of Freedom	Mean Square
Total	159	---
Between Treatments	7	---
Type of Disk	1	0.0250
Storage Temperature	3	26.4666**
Type of Disk x Storage Temperature	3	0.8917
Within Treatments	152	---
Replication	1	0.0250
Taster	9	24.0944**
Taster x Replication	9	0.5250*
Taster x Treatments	63	1.1929**
Treatments x Replication	7	0.3107
Treatments x Taster x Replication	63	0.2234

** Statistical Significance 1% level
* " " 5% level

TABLE 19A

ANALYSIS OF VARIANCE OF SENSORY EVALUATION
OF AIR-DRIED CABBAGE FLAVOR

	Degrees of Freedom	Mean Square
Total	95	---
Between Treatments	5	---
Type of Disk	1	5.0416
Storage Temperature	2	1.1565
Type of Disk x Storage Temperature	2	0.5102
Within Treatments	90	---
Replication	1	3.3750
Taster	7	27.7559**
Taster x Replication	7	0.7560
Taster x Treatment	35	1.7703
Treatments x Replication	5	1.7750
Treatments x Taster x Replication	35	1.3559

** Statistical Significance 1% level

TABLE 19B

ANALYSIS OF VARIANCE OF SENSORY EVALUATION
OF AIR-DRIED CABBAGE ODOR

	Degrees of Freedom	Mean Square
Total	95	---
Between Treatments	5	---
Type of Disk	1	0.3750
Storage Temperature	2	0.0935
Type of Disk x Storage Temperature	2	0.2190
Within Treatments	90	---
Replication	1	0.0420
Taster	7	17.3987**
Taster x Replication	7	0.1133
Taster x Treatments	35	0.3381
Treatments x Replication	5	0.7166
Treatments x Taster x Replication	35	0.4452

** Statistical Significant, 1% level

TABLE 20

THE EFFECT OF STORAGE TEMPERATURE ON THE FLAVOR AND ODOR OF THE LAMINATED AND CONTROL PINEAPPLE DISKS

Storage Temperatures (°F)	Means of Main Effects Hedonic Scale Ratings: Laminated Disks Flavor	Laminated Disks Odor	Control Disks Flavor	Control Disks Odor
0 to 40	7.5	6.8	7.5	6.8
40	7.4	6.4	7.2	7.0
70	7.4	6.8	6.9	6.7
100	5.0	5.5	5.1	5.8

Hedonic Scale (1-9, most liked)

TABLE 21

THE EFFECT OF STORAGE TEMPERATURE ON THE FLAVOR AND ODOR OF THE LAMINATED AND CONTROL ONION DISKS

Storage Temperatures (°F)	Means of Main Effects Hedonic Scale Ratings: Laminated Disks Flavor	Laminated Disks Odor	Control Disks Flavor	Control Disks Odor
0 to 40	4.2	5.0	4.4	5.0
40	4.3	5.1	4.2	4.9
70	4.7	5.0	4.1	4.9
100	5.2	4.8	4.7	4.6

Hedonic Scale (1-9, most liked)

TABLE 22

THE EFFECT OF STORAGE TEMPERATURE ON THE FLAVOR AND ODOR OF THE LAMINATED AND CONTROL COOKIES

Storage Temperatures (°F)	Means of Main Effects Hedonic Scale Ratings			
	Laminated Disks		Control Disks	
	Flavor	Odor	Flavor	Odor
0 to 40	6.4	5.6	6.5	5.4
40	5.8	5.3	6.4	5.5
70	6.1	5.3	5.6	5.2
100	5.4	5.1	3.5	4.1

Hedonic Scale (1-9, most liked)

TABLE 23

THE EFFECT OF STORAGE TEMPERATURE ON THE FLAVOR AND ODOR OF THE LAMINATED AND CONTROL CARAMEL DISKS

Storage Temperatures (°F)	Means of Main Effects Hedonic Scale Ratings			
	Laminated Disks		Control Disks	
	Flavor	Odor	Flavor	Odor
0 to 40	7.0	6.0	7.1	5.2
40	7.1	5.8	7.2	5.3
70	7.2	5.8	7.3	6.0
100	7.0	5.9	7.1	5.8

Hedonic Scale (1-9, most liked)

TABLE 24

THE EFFECT OF STORAGE TEMPERATURE ON THE FLAVOR AND ODOR OF THE LAMINATED AND CONTROL CARROT DISKS

Storage Temperatures (°F)	Means of Main Effects Hedonic Scale Ratings			
	Laminated Disks		Control Disks	
	Flavor	Odor	Flavor	Odor
0 to 40	5.2	4.5	5.0	4.8
40	4.7	4.4	4.7	4.5
70	4.7	4.7	4.7	4.6
100	4.7	5.2	4.9	5.2

Hedonic Scale (1-9, most liked)

TABLE 25

THE EFFECT OF STORAGE TEMPERATURE ON THE FLAVOR AND ODOR OF THE LAMINATED AND CONTROL STRAWBERRY DISKS

Storage Temperatures (°F)	Means of Main Effects Hedonic Scale Ratings			
	Laminated Disks		Control Disks	
	Flavor	Odor	Flavor	Odor
0 to 40	7.5	7.7	7.3	7.3
40	7.3	7.4	7.4	7.4
70	6.6	7.1	6.8	7.2
100	5.1	5.6	5.3	5.9

Hedonic Scale (1-9, most liked)

TABLE 26

THE EFFECT OF STORAGE TEMPERATURE ON THE FLAVOR AND ODOR OF THE LAMINATED AND CONTROL CABBAGE DISKS

Storage Temperatures (°F)	Means of Main Effects Hedonic Scale Ratings			
	Laminated Disks		Control Disks	
	Flavor	Odor	Flavor	Odor
0 to 40	4.2	5.0	4.6	5.2
40	4.1	4.9	4.7	5.1
70	4.6	5.1	4.7	5.1

Hedonic Scale (1-9 most liked)

TABLE 27

THE EFFECT OF STORAGE TEMPERATURE ON THE COLOR OF THE LAMINATED AND CONTROL PINEAPPLE DISKS

Storage Temperatures (°F)	Storage Time (Month)	Per Cent Reflectance at Selected Wavelengths					
		Laminated Disks			Control Disks		
		530mμ	565mμ	600mμ	530mμ	565mμ	600mμ
-	0	75	80	83	75	81	84
0 to 40	3	81	85	87	81	85	87
40	3	79	83	86	82	86	88
70	3	77	83	85	78	82	86
100	3	59	65	72	61	67	73

TABLE 28

THE EFFECT OF STORAGE TEMPERATURE ON THE COLOR OF THE LAMINATED AND CONTROL ONION DISKS

Storage Temperatures (°F)	Storage Time (Months)	Per Cent Reflectance at Selected Wavelengths					
		Laminated Disks			Control Disks		
		490mμ	535mμ	580mμ	490mμ	535mμ	580mμ
-	0	86	90	93	86	90	93
0 to 40	3	84	88	90	84	88	90
40	3	84	89	90	84	89	90
70	3	86	90	92	85	90	91
100	3	70	78	83	74	81	85

TABLE 29

THE EFFECT OF STORAGE TEMPERATURE ON THE COLOR OF THE LAMINATED AND CONTROL COOKIES

Storage Temperatures (°F)	Storage Time (Months)	Per Cent Reflectance at Selected Wavelengths					
		Laminated Disks			Control Disks		
		575mμ	640mμ	700mμ	575mμ	640mμ	700mμ
-	0	37	57	63	39	53	64
0 to 40	3	32	45	56	33	46	57
40	3	33	48	57	33	48	57
70	3	34	49	59	34	49	59
100	3	39	52	63	38	51	62

TABLE 30

THE EFFECT OF STORAGE TEMPERATURE ON THE COLOR
OF THE LAMINATED AND CONTROL CARAMEL DISKS

Storage Temperatures (°F)	Per Cent Reflectance at Selected Wavelengths					
	Laminated Disks			Control Disks		
	575mμ	640mμ	700mμ	575mμ	640mμ	700mμ
Original	31	43	53	18	27	37
0 to 40	26	35	43	18	28	36
40	24	33	41	21	31	38
70	23	31	39	20	29	38
100	26	35	43	17	25	34

TABLE 31

THE EFFECT OF STORAGE TEMPERATURE ON THE COLOR
OF THE LAMINATED AND CONTROL CARROT DISKS

Storage Temperatures (°F)	Storage Time (Months)	Per Cent Reflectance at Selected Wavelengths					
		Laminated Disks			Control Disks		
		530 mμ	590 mμ	650 mμ	530 mμ	590 mμ	650 mμ
--	0	49.8	74.3	79.2	48.8	73.2	78.0
0 to 40	3	63.3	85.5	90.0	84.0	91.5	94.0
40	3	71.0	82.0	86.5	74.1	84.5	88.5
70	3	66.0	89.0	93.5	71.0	89.9	93.5
100	3	78.1	91.0	93.5	77.8	91.0	93.5

TABLE 32

THE EFFECT OF STORAGE TEMPERATURE ON THE COLOR OF THE LAMINATED AND CONTROL STRAWBERRY DISKS

Storage Temperatures (°F)	Storage Time (Months)	Per Cent Reflectance at Selected Wavelengths: Laminated Disks 580 mμ	640 mμ	700 mμ	Control Disks 580 mμ	640 mμ	700 mμ
--	0	28.0	60.0	79.8	26.0	56.7	75.0
0 to 40	3	28.0	61.0	79.0	30.0	64.0	81.0
40	3	26.0	57.0	65.0	29.8	63.0	79.8
70	3	24.8	54.0	72.0	26.0	58.0	77.0
100	3	19.5	39.0	51.0	27.0	48.0	59.6

TABLE 33

THE EFFECT OF STORAGE TEMPERATURE ON THE COLOR OF THE LAMINATED AND CONTROL CABBAGE DISKS

Storage Temperature (°F)	Storage Time (Months)	Per Cent Reflectance at Selected Wavelengths: Laminated Disks 490mμ	555mμ	620mμ	665mμ	Control Disks 490mμ	555mμ	620mμ	665mμ
--	0	31.0	43.8	47.5	41.3	31.0	43.8	49.0	43.2
0 to 40	3	31.8	45.5	49.0	41.8	32.8	47.0	51.2	42.2
40	3	31.5	45.5	51.2	44.7	35.0	49.0	55.0	48.8
70	3	30.0	43.0	50.5	45.0	31.5	46.5	53.0	47.5
100	3	18.0	26.0	32.0	35.5	15.9	23.5	29.2	35.0

TABLE 34

MOISTURE CONTENT (WET BASIS) OF PINEAPPLE
BEFORE AND AFTER 3 MONTHS STORAGE

Type of Disk	Before Storage		After Storage 3-Months			
	Raw Material	0-Months	0 to 40°F	40°F	70°F	100°F
Control	2.77	3.49	3.46	3.53	3.63	3.59
Laminated	2.77	4.01	3.42	3.51	3.97	4.17

TABLE 35

MOISTURE CONTENT OF ONIONS
BEFORE AND AFTER 3 MONTHS STORAGE

Type of Disk	Before Storage		After Storage 3-Months			
	Raw Material	0-Months	0 to 40°F	40°F	70°F	100°F
Control	1.97	2.94	2.72	2.60	2.74	2.73
Laminated	1.97	3.26	2.88	2.95	2.63	3.27

TABLE 36

MOISTURE CONTENT OF COOKIES
BEFORE AND AFTER 3-MONTHS STORAGE

Type of Disk	Before Storage	After Storage			
		0 to 40°F	40°F	70°F	100°F
Control	4.81	5.43	5.48	4.69	6.14
Laminated	3.74	2.93	3.29	3.30	4.94

TABLE 37

MOISTURE CONTENT OF CARAMEL
DISKS BEFORE AND AFTER 3-MONTHS STORAGE

Type of Disk	Before Storage	After Storage			
		0 to 40°F	40°F	70°F	100°F
Control	5.40	3.58	2.78	4.16	3.71
Laminated	2.93	2.07	2.30	2.67	2.30

TABLE 38

MOISTURE CONTENT OF CARROTS
BEFORE AND AFTER 3-MONTHS STORAGE

Type of Disk	Before Storage		After Storage 3-Months			
	Raw Material	0-Months	0 to 40°F	40°F	70°F	100°F
Control	4.33	4.51	3.98	4.46	3.94	4.03
Laminated	4.33	4.69	4.75	5.21	4.68	4.76

TABLE 39

MOISTURE CONTENT OF STRAWBERRIES
BEFORE AND AFTER 3-MONTHS STORAGE

Type of Disk	Before Storage		After Storage 3-Months			
	Raw Material	0-Months	0 to 40°F	40°F	70°F	100°F
Control	4.48	4.39	4.89	5.24	5.60	5.50
Laminated	4.48	4.96	4.34	3.47	4.81	5.63

TABLE 40

MOISTURE CONTENT OF CABBAGE
BEFORE AND AFTER 3-MONTHS STORAGE

Type of Disk	Before Storage		After Storage 3-Months			
	Raw Material	0-Months	0 to 40°F	40°F	70°F	100°F
Control	4.80	8.71	9.96	9.49	10.46	10.30
Laminated	4.80	8.74	9.09	7.62	8.76	8.78

TABLE 41

SUGAR CONTENT OF PINEAPPLE DISKS
BEFORE AND AFTER 3-MONTHS STORAGE

Type of Disk	Storage Time (Months)	Storage Temperature (°F)	Means of Main Effects Sugars Non-Reducing Per Cent	Reducing Per Cent *	Total Per Cent *
-	0	-	53.4	27.6	81.0
Control	3	0 to 40	48.5	29.9	78.4
Control	3	40	52.1	27.9	80.0
Control	3	70	49.0	29.4	78.4
Control	3	100	47.3	31.1	78.4
Laminated	3	0 to 40	50.9	28.6	79.5
Laminated	3	40	51.0	28.1	79.1
Laminated	3	70	46.8	32.1	78.9
Laminated	3	100	46.4	34.1	80.5

* as % invert

SUGAR CONTENT OF ONION DISKS
BEFORE AND AFTER 3 MONTHS STORAGE

Type of Disk	Storage Time (Months)	Storage Temperature (°F)	Means of Main Effects Sugars Non-Reducing Per Cent	Reducing Per Cent*	Total Per Cent*
-	0	-	35.5	33.6	69.1
Control	3	0 to 40	27.2	36.7	63.9
Control	3	40	30.5	37.2	67.7
Control	3	70	29.3	34.1	63.4
Control	3	100	29.8	34.1	63.9
Laminated	3	0 to 40	32.8	32.6	65.4
Laminated	3	40	35.9	37.2	73.1
Laminated	3	70	43.8	34.6	78.4
Laminated	3	100	40.8	31.6	72.4

* as % invert

TABLE 43

SUGAR CONTENT OF COOKIES BEFORE
AND AFTER 3-MONTHS STORAGE

Type of Disk	Storage Time (Months)	Storage Temperature (°F)	Means of Main Effects Sugars Non-Reducing Per Cent	Reducing Per Cent*	Total Per Cent*
-	0	-	45.0	9.7	54.7
Control	3	0 to 40	44.5	11.7	56.2
Control	3	40	38.2	15.9	54.1
Control	3	70	42.8	12.4	55.2
Control	3	100	43.3	11.4	54.7
Laminated	3	0 to 40	45.0	12.2	57.2
Laminated	3	40	45.0	12.2	57.2
Laminated	3	70	44.8	10.4	55.2
Laminated	3	100	46.8	9.9	56.7

* as % invert

TABLE 44

SUGAR CONTENT OF CARAMEL DISKS
BEFORE AND AFTER 3-MONTHS STORAGE

Type of Disk	Storage Time (Months)	Storage Temperature (°F)	Means of Main Effects Sugars Non-Reducing Per Cent	Reducing Per Cent*	Total Per Cent*
-	0	-	42.4	23.0	65.4
Control	3	0 to 40	41.6	26.9	68.5
Control	3	40	48.1	26.6	74.7
Control	3	70	40.9	29.7	70.6
Control	3	100	42.5	30.6	73.1
Laminated	3	0 to 40	43.2	23.2	66.4
Laminated	3	40	48.1	23.0	71.1
Laminated	3	70	43.0	30.6	73.6
Laminated	3	100	41.2	35.1	76.3

* as % invert

TABLE 45

SUGAR CONTENT OF CARROTS
BEFORE AND AFTER 3-MONTHS STORAGE

Type of Disk	Storage Time (Months)	Storage Temperature (°F)	Means of Main Effects Sugars Non-Reducing Per Cent	Reducing Per Cent*	Total Per Cent*
Control	0	-	27.9	26.6	54.5
Control	3	0 to 40	27.6	27.6	55.2
Control	3	40	27.6	27.6	55.2
Control	3	70	27.4	24.6	52.0
Control	3	100	22.9	21.4	44.3
Laminated	0	-	29.1	26.1	55.2
Laminated	3	0 to 40	28.6	26.6	56.2
Laminated	3	40	27.5	26.6	54.1
Laminated	3	70	26.4	26.6	53.0
Laminated	3	100	21.9	21.4	43.3

* as % invert

TABLE 46

SUGAR CONTENT OF STRAWBERRIES
BEFORE AND AFTER 3-MONTHS STORAGE

Type of Disk	Storage Time (Months)	Storage Temperature (°F)	Means of Main Effects Sugars: Non-Reducing Per Cent	Reducing Per Cent*	Total Per Cent*
--	0	-	9.2	55.2	64.4
Control	3	0 to 40	10.4	53.0	63.4
Control	3	40	10.9	53.5	64.4
Control	3	70	12.7	46.5	59.2
Control	3	100	13.4	43.8	57.2
Laminated	3	0 to 40	9.7	54.0	63.7
Laminated	3	40	5.1	57.2	62.3
Laminated	3	70	8.2	48.0	56.2
Laminated	3	100	14.4	43.8	58.2

* as % invert

TABLE 47

SUGAR CONTENT OF CABBAGE
BEFORE AND AFTER 3-MONTHS STORAGE

Type of Disk	Storage Time (Months)	Storage Temperature (°F)	Means of Main Effects Sugars: Non-Reducing Per Cent	Reducing Per Cent*	Total Per Cent*
--	0	-	16.4	50.0	66.4
Control	3	0 to 40	14.4	43.8	58.2
Control	3	40	8.2	44.8	53.0
Control	3	70	7.2	42.8	50.0
Control	3	100	8.2	39.8	48.0
Laminated	3	0 to 40	12.3	45.9	58.2
Laminated	3	40	9.7	43.8	53.5
Laminated	3	70	7.2	42.8	50.0
Laminated	3	100	7.2	40.3	47.5

* as % invert

TABLE 48

TOTAL BACTERIA OF ONION DISKS
BEFORE AND AFTER 3-MONTHS STORAGE

Type of Disk	Storage Time (Months)	Storage Temperature (°F)	Standard Plate Count Per Gram
Control	0	-	<300
Control	3	0 to 40	1200
Control	3	40	1200
Control	3	70	670
Control	3	100	<300
Laminated	0	-	<300
Laminated	3	0 to 40	3000
Laminated	3	40	770
Laminated	3	70	2300
Laminated	3	100	<300

TABLE 49

TOTAL BACTERIA OF CARAMEL DISKS
BEFORE AND AFTER 3-MONTHS STORAGE

Type of Disk	Storage Time (Months)	Storage Temperature (°F)	Standard Plate Count Per Gram
Control	0	-	<300
Control	3	0 to 40	<300
Control	3	40	<300
Control	3	70	<300
Control	3	100	<300
Laminated	0	-	<300
Laminated	3	0 to 40	1200
Laminated	3	40	1000
Laminated	3	70	460
Laminated	3	100	<300

TABLE 50

TOTAL BACTERIA OF CARROT DISKS
BEFORE AND AFTER 3-MONTHS STORAGE

Type of Disk	Storage Time (Months)	Storage Temperature (°F)	Standard Plate Count Per Gram
Control	0	--	<300
Control	3	0 to 40	410
Control	3	40	2800
Control	3	70	<300
Control	3	100	<300
Laminated	0	--	<300
Laminated	3	0 to 40	520
Laminated	3	40	<300
Laminated	3	70	380
Laminated	3	100	<300

TABLE 51

TOTAL BACTERIA OF CABBAGE DISKS
BEFORE AND AFTER 3-MONTHS STORAGE

Type of Disk	Storage Time (Months)	Storage Temperature (°F)	Standard Plate Count Per Gram
Control	0	--	600
Control	3	0 to 40	540
Control	3	40	450
Control	3	70	<300
Control	3	100	<300
Laminated	0	--	470
Laminated	3	0 to 40	460
Laminated	3	40	<300
Laminated	3	70	430
Laminated	3	100	<300

TABLE 52

SEPARABILITY OF LAMINATES (PERCENT)
AFTER 3-MONTHS STORAGE

Food	Number of Laminates	0 to 40°F	Storage Temperatures 40°F	70°F	100°F
High Cook Caramel	5	78.0	62.0	84.0	30.0
Non-Leavened Cookie	4	77.5	77.5	92.5	95.0
Freeze Dried Onions	6	50.0	21.7	46.7	20.0
Freeze Dried Pineapple	6	71.7	61.7	75.0	11.7
Freeze Dried Strawberries	7	31.4	57.1	44.3	1.4
Freeze Dried Carrots	5	16.0	25.0	18.0	38.0
Air Dried Cabbage	7	100.0	100.0	100.0	100.0

TABLE 53

REHYDRATABILITY OF PINEAPPLE CONTROL DISKS BEFORE AND AFTER 3-MONTHS STORAGE

Storage Temperature (°F)	Storage Time (Months)	Rehydration Water Temperature (°F)	Per Cent Rehydration After 5 Minutes
-	0	78	10.0
-	0	170	23.7
0 to 40	3	78	10.7
0 to 40	3	170	41.0
40	3	78	10.4
40	3	170	36.4
70	3	78	10.2
70	3	170	40.8
100	3	78	9.0
100	3	170	29.7

TABLE 54

REHYDRATABILITY OF PINEAPPLE LAMINATES BEFORE AND AFTER 3-MONTHS STORAGE

Storage Temperature (°F)	Storage Time (Months)	Rehydration Water Temperature (°F)	100% Rehydration Time (Min.)
-	0	78	19.0
-	0	170	3.0
0 to 40	3	78	> 30
0 to 40	3	170	3.5
40	3	78	> 30
40	3	170	4.5
70	3	78	> 30
70	3	170	3.5
100	3	78	> 30
100	3	170	5.5

TABLE 55

REHYDRATABILITY OF ONION CONTROL DISKS
BEFORE AND AFTER 3-MONTHS STORAGE

Storage Temperature (°F)	Storage Time (Months)	Rehydration Temperature (°F)	Per Cent Rehydration After 5 Minutes
-	0	78	22.9
-	0	170	36.9
0 to 40	3	78	8.3
0 to 40	3	170	31.8
40	3	78	10.1
40	3	170	36.0
70	3	78	10.7
70	3	170	31.7
100	3	78	10.8
100	3	170	25.4

TABLE 56

REHYDRATABILITY OF ONION LAMINATES
BEFORE AND AFTER 3-MONTHS STORAGE

Storage Temperature (°F)	Storage Time (Months)	Rehydration Temperature (°F)	Per Cent Rehydration After 5 Minutes
-	0	78	10.0
-	0	170	0.75
0 to 40	3	78	>30
0 to 40	3	170	1.75
40	3	78	>30
40	3	170	2.0
70	3	78	>30
70	3	170	1.25
100	3	78	>30
100	3	170	2.50

TABLE 57

REHYDRATION OF CARROT CONTROL DISK
BEFORE AND AFTER 3-MONTHS STORAGE

Storage Temperature (°F)	Storage Time (Months)	Rehydration Water Temperature (°F)	Per Cent Rehydration After 30 Minutes
-	0	78	16.9*
-	0	170	35.5*
0 to 40	3	78	27.1
0 to 40	3	170	36.8
40	3	78	29.8
40	3	170	36.8
70	3	78	28.6
70	3	170	40.4
100	3	78	24.6
100	3	170	41.7

* After 5 minutes

TABLE 58

REHYDRATION OF CARROT LAMINATES
BEFORE AND AFTER 3-MONTHS STORAGE

Storage Temperature (°F)	Storage Time (Months)	Rehydration Water Temperature (°F)	100% Rehydration Time (Min.)
-	0	78	17
-	0	170	2.5
0 to 40	3	78	27
0 to 40	3	170	2.0
40	3	78	22
40	3	170	1.75
70	3	78	19
70	3	170	2.25
100	3	78	21
100	3	170	2.75

TABLE 59

REHYDRATION OF STRAWBERRY CONTROL DISK
BEFORE AND AFTER 3-MONTHS STORAGE

Storage Temperature (°F)	Storage Time (Months)	Rehydration Water Temperature (°F)	Per Cent Rehydration After 30 Minutes
-	0	78	11.4*
-	0	170	30.0*
0 to 40	3	78	17.1
0 to 40	3	170	49.0
40	3	78	17.1
40	3	170	46.9
70	3	78	18.4
70	3	170	42.7
100	3	78	20.6
100	3	170	43.6

* After 5 minutes

TABLE 60

REHYDRATION OF STRAWBERRY LAMINATES
BEFORE AND AFTER 3-MONTHS STORAGE

Storage Temperature (°F)	Storage Time (Months)	Rehydration Water Temperature (°F)	100% Rehydration Time (Min.)
-	0	78	18
-	0	170	3.5
0 to 40	3	78	26
0 to 40	3	170	5.0
40	3	78	27
40	3	170	4.0
70	3	78	34
70	3	170	7.0
100	3	78	32
100	3	170	5.0

TABLE 61

REHYDRATABILITY OF CABBAGE CONTROL
DISK BEFORE AND AFTER 3-MONTHS STORAGE

Storage Temperature (°F)	Storage Time (Months)	Rehydration Water Temperature (°F)	Rehydration Time	Per Cent Rehydration
-	0	78	5	9.5
-	0	170	4.5	100
0 to 40	3	78	35	41.8
0 to 40	3	170	6.75	100
40	3	78	35	30.7
40	3	170	8.5	100
70	3	78	35	15.3
70	3	170	10.0	100
100	3	78	35	39.9
100	3	170	11.0	100

TABLE 62

REHYDRATION OF CABBAGE LAMINATES
BEFORE AND AFTER 3-MONTHS STORAGE

Storage Temperature (°F)	Storage Time (Months)	Rehydration Water Temperature (°F)	100% Rehydration Time (Min.)
-	0	78	16
-	0	170	0.5
0 to 40	3	78	13
0 to 40	3	170	0.5
40	3	78	18
40	3	170	0.5
70	3	78	20.0
70	3	170	0.5
100	3	78	19.0
100	3	170	0.75

TABLE 63 - FORMATION OF LAMINATED BARS

Food	Moisture Content (% dry basis)	Bar Weight (gm)	Number of Laminates	Press & Dwell to laminate (psi/sec)	Dimensions (mm)	Density (gm/cc)	Laminate Hardness	Bar Cohesiveness
Rice-beef-pea combination	11.1	17.5	7	1000/60	12.8 x 29.6 x 44.9	1.028	slight	excellent
Freeze dried Strawberries	4.14	14.0	7	500/5	12.8 x 23.1 x 45.8	1.034	moderate	excellent
Freeze Dried Carrots	6.60	17.0	8	750/30	13.3 x 32.8 x 45.3	0.860	moderate	good

TABLE 64 - FORMATION OF CONTROL AND COMPRESSION ORIENTATED BARS

Food	Moisture Content (%)	Bar Weight (gm)	Die Set (inches)	Press & Dwell to laminate (psi/sec)	Dimensions (mm)	Density (gm/cc)	Laminate Hardness	Bar Cohesiveness
Rice-beef-pea Combination	11.1	17.5	1/2 x 1-3/4	4000/60	12.8 x 29.4 x 44.8	1.038	moderate	excellent
Freeze dried Strawberries	4.14	14.0	1/2 x 1-3/4	3000/60	12.8 x 22.9 x 45.8	1.043	extreme	excellent
Freeze Dried Carrots Compression Orientated	6.60	17.0	1/2 x 1-3/4	4000/60	13.3 x 32.6 x 45.3	0.866	moderate	good
Freeze Dried Carrots (Control)	6.60	17.0	1-1/4 x 1-3/4	4000/60	13.2 x 32.8 x 45.3	0.867	extreme	good

TABLE 65

EVALUATION OF EXPERIMENTAL AND CONTROL SAMPLES STORED FOR 3 MONTHS

A. Casserole Bars *

Evaluation	0 to 40°F (cycling) Laminated	0 to 40°F (cycling) Control	100°F. Laminated	100°F. Control
Appearance	Good **	Good **	Good **	Good **
Biteability/Separability	Could be orally separated	Moderately Hard	Could be orally separated	Moderately Hard
Rehydration Time (min.)	1.75	3.00	1.50	2.00
Chemical-TBA (moles of malonaldehyde x 10 -8)	0.222	0.222	0.222	0.222
Microbiological (std. plate count/gm.)	$<$ 3000	$<$ 3000	$<$ 3000	$<$ 3000

B. F/D Strawberry Bars *

Evaluation	0 to 40°F (cycling) Laminate	0 to 40°F (cycling) Control	100°F Laminated	100°F Control
Appearance	Good **	Good **	Slightly darker color	Slightly darker color
Biteability/Separability	Could be orally separated	Extremely Hard	Could be orally separated	Extremely Hard
Rehydratability (%) ***	100	39.5	100	31.3
Chemical-Ascorbic Acid (%)	0.419	0.446	0.094	0.297
Microbiological (std. plate count/gm.)	10,200	7000	4700	5000

* In cans (evacuated-purged with nitrogen twice and sealed.)
** Little or no change over storage.
*** 30 minutes in 170°F water.

C. FREEZE-DRIED CARROT BARS*

EVALUATION	0 to 40°F (cycling) Laminated	0 to 40°F (cycling) Compression Orientated	0 to 40°F (cycling) Control	100°F Laminated	100°F Compression Orientated	100°F Control
Appearance	Good**	Good**	Good**	Good**	Good**	Good**
Biteability/ Separability	Could be orally separated	Moderately Hard	Extremely Hard	Could be orally separated	Moderately Hard	Very Hard
Rehydration Time (min.)	17	9	23	6	8	7
Chemical - B carotene (ppm, dry basis)	1167	1075	1140	698	700	669
Microbiological (Std. plate count/gm)	4700	5200	5000	<3000	<3000	<3000

* Stored in cans (evacuated - purged with nitrogen twice and sealed).

** Little or no change over storage

TABLE 66

HARDNESS/SEPARABILITY AND APPEARANCE DATA FOR CASSEROLE BARS STORED AT 0 to 40°F (cycling) FOR 3 MOS.

a. Laminated Bars

	Appearance	Separability	Damage
Pressure Sub Group			
Pressure Exerted on Side	Good *	Could be orally separated	3 laminates separated
Pressure Exerted on Face	Good *	Could be orally separated	-
Humidity Sub Group			
0%	Good *	Could be orally separated	
75%	Color Good * Some Crumbling	-	All laminates separated
Gaseous Oxygen Sub Group			
Purged w/ N_2 twice	Good *	Could be orally separated	-
Purged w/ N_2 once	Good *	Could be orally separated	-
Air	Good *	Could be orally separated	2 laminates separated

* Little or no change over storage.

TABLE 66 Continued

HARDNESS/SEPARABILITY AND APPEARANCE DATA FOR CASSEROLE BARS STORED AT 0 to 40°F (cycling) FOR 3 MOS.

b. Control Bars

	Appearance	Hardness
Pressure Sub Group		
Pressure Exerted on Side	Good *	Moderately Hard
Pressure Exerted on Face	Good *	Moderately Hard
Humidity Sub Group		
0%	Good *	Moderately Hard
75%	Color Good * Some Crumbling	Slightly Hard
Gaseous Oxygen Sub Group		
Purged w/ N_2 twice	Good *	Moderately Hard
Purged w/ N_2 once	Good *	Moderately Hard
Air	Good *	Moderately Hard

* Little or no change over storage.

BITEABILITY AND APPEARANCE DATA FOR CASSEROLE BARS STORED

AT 100° F FOR 3 MONTHS

a. Laminated Bars

	Appearance	Damage
Pressure Sub Groups		
Pressure Exerted on Side	Good *	-
Pressure Exerted on Face	Good *	-
Humidity Sub Group		
0%	Good *	-
75%	Peas bleached Some crumbling	3 laminates separated
Gaseous Oxygen Sub Groups		
Purged w/ N_2 twice	Good *	-
Purged w/ N_2 once	Good *	-
Air	Good *	-

* Little or no change over storage.

b. Control Bars

	Appearance	Hardness
Pressure Sub Groups		
Pressure Exerted on Side	Good *	Moderately Hard
Pressure Exerted on Face	Good *	Moderately Hard
Humidity Sub Groups		
0%	Good *	Slightly Hard
75%	Peas bleached Some crumbling	Slightly Hard
Gaseous Oxygen Sub Groups		
Purged w N_2 twice	Good *	Moderately Hard
Purged w/ N_2 once	Good *	Moderately Hard
Air	Good *	Moderately Hard

* Little or no change over storage.

TABLE 68

REHYDRATABILITY DATA FOR LAMINATED CASSEROLE BARS STORED FOR 3 MONTHS

0 to 40°F (cycling) Storage Temperature		100°F Storage Temperature	
Rehydration Time (Min.)		Rehydration Time (Min.)	
Pressure Sub Group		Pressure Sub Group	
Pressure Exerted on Side	1.50	Pressure Exerted on Side	3.00
Pressure Exerted on Face	1.50	Pressure Exerted on Face	1.00
Humidity Sub Group		Humidity Sub Group	
0%	3.00	0%	1.50
75%	1.00	75%	3.00
Gaseous Oxygen Sub Group		Gaseous Oxygen Sub Group	
Purged w/ N_2 twice	1.75	Purged w N_2 twice	1.50
Purged w/ N_2 once	2.00	Purged w/ N_2 once	1.50
Air	1.50	Air	1.50

TABLE 60

TASTE PANEL DATA FOR CASSEROLE BARS

STORED FOR 3 MONTHS AT 100°F and 0 to 40°F (cycling)

Means of Scores

Preference / Difference

Pressure

Pressure Sub Group	Temp. (°F)	S *	NS +	Pressure Sub Group	Temp. (°F)	S *	NS +
Pressure Exerted On Side	0 to 40	1.6	2.2	Pressure Exerted On Side	0 to 40	2.8	2.8
	100	2.0	2.0		100	2.6	2.2
Pressure Exerted On Face	0 to 40	1.8	2.2	Pressure Exerted On Face	0 to 40	3.0	2.2
	100	2.4	2.4		100	2.8	2.8

Humidity

Humidity Sub Group	Temp. (°F)	s *	NS +	Humidity Sub Group	Temp. (°F)	S *	NS +
0%	0 to 40	1.8	2.6	0%	0 to 40	2.8	2.2
	100	1.6	2.0		100	2.6	2.0
75%	0 to 40	2.2	2.0	75%	0 to 40	1.8	2.0
	100	1.0	1.8		100	3.4	3.2

Samples: Sig. at the 5% level.

Gaseous Oxygen

Gaseous Oxygen Sub Group	Temp. (°F)	S *	NS +	Gaseous Oxygen Sub Group	Temp. (°F)	S *	NS +
Purged with N_2 twice	0 to 40	2.0	2.2	Purged with N_2 twice	0 to 40	3.0	1.8
	100	2.2	2.6		100	2.8	2.4
Purged with N_2 once	0 to 40	2.0	2.2	Purged with N_2 once	0 to 40	2.2	1.6
	100	2.4	1.6		100	3.6	4.2
Air	0 to 40	2.2	2.0	Air	0 to 40	1.8	2.0
	100	2.4	2.6		100	4.0	4.0

* Sample with the softening mechanism

\+ Sample without the softening mechanism

TABLE 70

STATISTICAL ANALYSIS OF TASTE PANEL DATA

FOR CASSEROLE BARS STORED AT 100°F AND

0 to 40°F (cycling) FOR 3 MONTHS

Pressure

Preference

Source of Variation	d/f	MS
Samples	1	0.62500
Interaction	3	0.22500
Residual	32	0.43750
Error	3	-
Total	39	-

Difference

Source of Variation	d/f	MS
Samples	1	0.90000
Interaction	3	0.36667
Residual	32	1.18750
Error	3	-
Total	39	-

Humidity

Preference

Source of Variation	d/f	MS
Samples	1	2.50000*
Interaction	3	0.70000
Residual	32	0.45000
Error	3	-
Total	39	-

Difference

Source of Variation	d/f	MS
Samples	1	0.90000
Interaction	3	0.36667
Residual	32	1.11250
Error	3	-
Total	39	-

Gaseous Oxygen

Preference

Source of Variation	d/f	MS
Samples	1	0
Interaction	5	0.48000
Residual	48	0.56667
Error	5	-
Total	59	-

Difference

Source of Variation	d/f	MS
Samples	1	0.81667
Interaction	5	1.01667
Residual	48	0.86667
Error	5	-
Total	59	-

* Significant at 5% level.

TABLE 71

CHEMICAL DATA FOR SOFTENED BARS STORED FOR 3 MONTHS

a. Casserole - TBA (No. of Moles of Malonaldehyde x 10^{-8} - Bone Dry Sample)

Pressure Sub Groups	0 to 40°F (cycling)	100°F
Pressure Exerted on Side	0.299	0.222
Pressure Exerted on Face	0.077	0.261
Humidity Sub Groups		
0%	0.201	0.225
75%	0.236	0.276
Gaseous Oxygen Sub Groups		
Purged with N_2 twice	0.222	0.222
Purged with N_2 once	0.261	0.222
Air	0.111	0.149

b. Freeze Dried Strawberries - Ascorbic Acid (% of Bone Dry Sample)

Pressure Sub Groups	0 to 40°F (cycling)	100°F
Pressure Exerted on Side	0.434	0.268
Pressure Exerted on Face	0.459	0.271
Humidity Sub Groups		
0%,	0.270	0.354
75%	0.289	0.001
Gaseous Oxygen Sub Groups		
Purged with N_2 twice	0.419	0.094
Purged with N_2 once	0.404	0.250
Air	0.375	0.240

(c.) Freeze Dried Carrots - B carotene (ppm dry wt basis)

	0 to 40°F (cycling)		100°F	
	Laminated	Compression Orientated	Laminated	Compression Orientated
Pressure Sub Groups				
Pressure exerted on side	986	1164	9	14
Pressure exerted on face	900	1068	12	17
Humidity Sub Groups				
0%	169	1085	2	6
75%	1099	868	24	24
Gaseous Oxygen Sub Groups				
Purged with N_2 twice	1167	1075	689	700
Purged with N_2 once	1088	986	677	695
Air	986	986	175	318

TABLE 72

MOISTURE CONTENTS OF LAMINATED SAMPLES STORED 3 MONTHS AT 0% R.H. and 75% R.H.

a. Casserole Bars *

0% R.H.		75% R.H.	
0 to 40°F	100°F	0 to 40°F	100°F
2.43	0.59	15.91	15.32

* Moisture content at 0-months storage - 9.99%

b. Freeze Dried Strawberry Bars *

0% R.H.		75% R.H.	
0 to 40°F	100°F	0 to 40°F	100°F
2.66	2.90	19.08	22.92

* Moisture content at 0-months storage - 4.14%

TABLE 73

HEADSPACE GAS ANALYSIS (%) OF BAR CONTAINERS STORED FOR 3 MONTHS

a. Casserole	0 to 40°F (Cycling)		100°F	
	O_2	CO_2	O_2	CO_2
Pressure Sub Groups				
Pressure Exerted on Side	20.69	0.50	20.50	0.50
Pressure Exerted on Face	20.68	0.50	14.05	4.30
Gaseous Oxygen Sub Groups				
Purged with N_2 twice	9.50	<0.50	8.83	0.75
Purged with N_2 once	18.37	<0.50	3.74	0.75
	18.03	<0.50	16.51	0.50
Air	20.85	<0.50	19.27	1.00
	21.33	<0.50	18.96	1.00

b. Freeze Dried Strawberries	0 to 40°F (Cycling)		100°F	
	O_2	CO_2	O_2	CO_2
Pressure Sub Groups				
Pressure Exerted on Side	20.87	<0.50	21.03	0.50
Pressure Exerted on Face	21.00	<0.50	14.81	6.75
Gaseous Oxygen Sub Group				
Purged with N_2 twice	4.34	<0.50	3.77	5.75
Purged with N_2 once	14.16	<0.50	12.88	2.25
	7.79	<0.50	19.41	1.75
Air	20.92	<0.50	19.45	2.25
	20.88	<0.50	18.42	1.00

c. Freeze Dried Carrots

	0 to 40°F (Cycling)		100°F	
	O_2	CO_2	O_2	CO_2
Pressure Sub Groups				
Pressure Exerted on Side	20.90	<0.50	20.75	<0.50
Pressure Exerted on Face	11.84	<0.50	20.84	<0.50
Gaseous Oxygen Sub Groups				
Purged with N_2 twice	9.69	<0.50	7.99	2.75
Purged with N_2 once	18.20	<0.50	18.73	0.50
Air	22.85	<0.50	11.19	3.00

TABLE 74

BITEABILITY AND APPEARANCE DATA FOR F/D STRAWBERRY

BARS STORED AT 0 to 40°F (cycling) FOR 3 MONTHS

a. Laminated Bars

	Appearance
Pressure Sub Group	
Pressure Exerted on Side	Good *
Pressure Exerted on Face	Good *
Humidity Sub Group	
0%	Good *
75%	Dark red color
Gaseous Oxygen Sub Group	
Purged w/ N_2 twice	Good *
Purged w/ N_2 once	Good *
Air	Good *

* Little or no change over storage.

b. Control Bars

	Appearance	Biteability
Pressure Sub Group		
Pressure Exerted on Side	Good *	Extremely Hard
Pressure Exerted on Face	Good *	Extremely Hard
Humidity Sub Group		
0%	Good *	Extremely Hard
75%	Dark red color	Slightly Hard
Gaseous Oxygen Sub Group		
Purged w/ N_2 twice	Good *	Extremely Hard
Purged w/ N_2 once	Good *	Extremely Hard
Air	Good *	Extremely Hard

* Little or no change over storage.

TABLE 75

BITEABILITY/SEPARABILITY AND APPEARANCE DATA FOR F/D STRAWBERRY BARS STORED AT 100°F FOR 3 MONTHS

a. Laminated Bars

	Appearance	Separability
Pressure Sub Group		
Pressure Exerted on Side	Slightly darker color	Had to be separated w/knife
Pressure Exerted on Face	Slightly darker color	Had to be separated w/knife
Humidity Sub Group		
0%	Good *	Could be orally separated
75%	Black color	Could be orally separated
Gaseous Oxygen Sub Group		
Purged w/ N_2 twice	Slightly darker color	Could be orally separated
Purged w/ N_2 once	Slightly darker color	Could be orally separated
Air	Slightly darker color	Could be orally separated

* Little or no change over storage.

b. Control Bars

	Appearance	Biteability
Pressure Sub Group		
Pressure Exerted on Side	Slightly darker color	Extremely Hard
Pressure Exerted on Face	Slightly darker color	Extremely Hard
Humidity Sub Group		
0%	Good *	Extremely Hard
75%	Black color	Slightly Hard
Gaseous Oxygen Sub Group		
Purged w/ N_2 twice	Slightly darker color	Extremely Hard
Purged w/ N_2 once	Slightly darker color	Extremely Hard
Air	Slightly darker color	Extremely Hard

* Little or no change over storage.

TABLE 76

TASTE PANEL DATA FOR STRAWBERRY BARS

STORED FOR 3 MONTHS AT 100°F and 0 to 40°F (cycling)

Means of Scores

Preference / Difference

Pressure

Pressure Sub Group	Temp. (°F)	S *	NS +	Pressure Sub Group	Temp. (°F)	S *	NS +
Pressure Exerted)	0 to 40	1.5	1.3	Pressure Exerted)	0 to 40	3.3	2.3
On Side)	100	1.8	1.8	On Side)	100	2.5	2.2
Pressure Exerted)	0 to 40	1.5	1.3	Pressure Exerted)	0 to 40	2.3	2.2
On Face)	100	1.8	2.2	On Face	100	2.2	1.8

Humidity

Humidity Sub Group	Temp. (°F)	S *	NS +	Humidity Sub Group	Temp. (°F)	S *	NS +
0%	0 to 40	1.7	1.8	0%	0 to 40	2.0	2.0
	100	1.7	1.7		100	3.2	2.3
75%	0 to 40	-	-	75%	0 to 40	-	-
	100	-	-		100	-	-

Gaseous Oxygen

Gaseous Oxygen Sub Group	Temp. (°F)	S *	NS +	Gaseous Oxygen Sub Group	Temp. (°F)	S *	NS +
Purged w/ N_2)	0 to 40	1.7	2.2	Purged w/ N_2)	0 to 40	2.2	1.7
twice)	100	1.8	1.5	twice)	100	2.2	2.5
Purged w/ N_2)	0 to 40	1.5	1.8	Purged w/ N_2)	0 to 40	2.2	2.2
once)	100	2.0	2.0	once)	100	1.8	2.0
Air	0 to 40	1.5	1.7	Air	0 to 40	2.5	1.3
	100	1.2	1.5		100	2.7	2.3

Samples: Sig. at the 5% level.

* Sample w/ the softening mechanism.

\+ Sample w/out the softening mechanism.

TABLE 77

STATISTICAL ANALYSIS OF TASTE PANEL DATA FOR F-D STRAWBERRY BARS STORED AT 100°F AND 0° TO 40°F FOR 3 MONTHS

Preference | Difference

Pressure

Source of Variation	d/f	MS	Source of Variation	d/f	MS
Samples	1	0	Samples	1	1.33333
Interaction	3	0.16667	Interaction	3	0.05556
Residual	40	0.47500	Residual	40	0.75833
Error	3	-	Error	3	-
Total	47	-	Total	47	-

Humidity

Source of Variation	d/f	MS	Source of Variation	d/f	MS
Samples	1	0.03166	Samples	1	0.16667
Interaction	1	0.04168	Interaction	1	0.16666
Residual	20	0.34317	Residual	20	0.33833
Error	1	-	Error	1	-
Total	23	-	Total	23	-

Gaseous Oxygen

Source of Variation	d/f	MS	Source of Variation	d/f	MS
Samples	1	1.35000*	Samples	1	1.1250
Interaction	5	0.47000	Interaction	5	0.8917
Residual	60	0.24167	Residual	60	0.8417
Error	5	-	Error	5	-
Total	71	-	Total	71	-

* Significance at the 5% level.

TABLE 78

MICROBIOLOGICAL DATA (STANDARD PLATE COUNT PER GRAM) FOR LAMINATED FREEZE DRIED STRAWBERRY BARS STORED FOR THREE MONTHS

	0 to 40°F (Cycling)	100°F
Pressure Sub Groups		
Pressure Exerted on Side	5000	3700
Pressure Exerted on Face	4800	3000
Humidity Sub Groups		
0%	7000	3400
75%	3000	3000
Gaseous Oxygen Sub Groups		
Purged with N_2 twice	10200	4700
Purged with N_2 once	6000	4200
Air	3100	7600

TABLE 72

APPEARANCE DATA FOR FREEZE DRIED CARROT BARS
STORED FOR 3 MONTHS

(a.) Laminated Bars

	0 to 40°F (cycling) Appearance	100°F Appearance
Pressure Sub Group		
Pressure exerted on side	Light orange	Very light orange
Pressure exerted on face	Light orange	Very light orange
Humidity Sub Group		
0%	Light orange	Light orange
75%	Dark orange	Light orange
Gaseous Oxygen Sub Group		
Purged with N_2 twice	Dark orange*	Dark orange*
Purged with N_2 once	Dark orange*	Dark orange*
Air	Dark orange*	Light orange

*Little or no change over storage.

(b.) Compression Orientated Bars

	0 to 40°F (cycling)		100°F	
	Appearance	Hardness	Appearance	Hardness
Pressure Sub Group				
Pressure exerted on side	Light orange	Moderate	Very light orange	Moderate
Pressure exerted on face	Light orange	Moderate	Very light orange	Slight
Humidity Sub Group				
0%	Dark orange*	Moderate	Very light orange	Moderate
75%	Dark orange	Slight	Light orange	Slight
Gaseous Oxygen Sub Group				
Purged with N_2 twice	Dark orange*	Moderate	Dark orange*	Moderate
Purged with N_2 once	Dark orange*	Moderate	Dark orange*	Moderate
Air	Dark orange*	Moderate	Light orange	Moderate

*Little or no change over storage.

(c.) Control Bars

Pressure Sub Group	0 to 40°F (cycling) Appearance	Hardness	100°F Appearance	Hardness
Pressure exerted on side	Very light orange	Extreme	Very light orange	Moderate
Pressure exerted on face	Very light orange	Extreme	Very light orange	Moderate
Humidity Sub Group				
0%	Very light orange	Moderate	Very light orange	Moderate
75%	Light orange	Slight	Very light orange	Slight
Gaseous Oxygen				
Purged with N_2 twice	Dark orange*	Extreme	Dark orange*	Very hard
Purged with N_2 once	Dark orange*	Extreme	Dark orange*	Very hard
Air	Dark orange*	Extreme	Light orange	Very hard

*Little or no change over storage.

TABLE 80

REHYDRATABILITY DATA FOR LAMINATED F/D CARROT BARS STORED FOR 3 MONTHS

	Rehydration Time (min.) 0 to 40°F (cycling)	100°F
Pressure Sub Groups		
Pressure Exerted On Side	4	16
Pressure Exerted On Face	4	21
Humidity Sub Groups		
0%	7	7
75%	1	3
Gaseous Oxygen Sub Groups		
Purged with N_2 twice	17	6
Purged with N_2 once	3	6
Air	6	5

TABLE 31

REHYDRATABILITY DATA FOR COMPRESSION ORIENTATED F/D CARROT BARS STORED FOR 3 MONTHS

	Rehydration Time (min.)	
	0 to 40°F (cycling)	100°F
Pressure Sub Groups		
Pressure Exerted On Side	4	18
Pressure Exerted On Face	4	31
Humidity Sub Groups		
0%	7	18
75%	1	*
Gaseous Oxygen Sub Groups		
Purged with N_2 twice	9	8
Purged with N_2 once	5	8
Air	8	10

* Bar completely moistened but not disintegrated after 30 minuts.

TABLE 82

TASTE PANEL DATA FOR F/D CARROT BARS STORED FOR 3 MONTHS AT 100°F AND 0 TO 40°F (CYCLING)

Means of Scores

Pressure

Preference: Pressure Sub Group	Temp. (°F)	S-1*	S-2**	NS***	Difference: Pressure Sub Group	Temp. (°F)	S-1*	S-2**	NS***
Pressure Exerted On Side	0 to 40	2.5	2.7	1.7	Pressure Exerted On Side	0 to 40	2.5	2.7	3.0
	100	1.7	1.5	1.7		100	2.7	3.0	2.8
Pressure Exerted On Face	0 to 40	2.3	2.5	1.7	Pressure Exerted On Face	0 to 40	2.3	2.5	1.7
	100	1.5	1.5	2.1		100	1.5	1.5	2.1

Humidity

Preference: Humidity Sub Group	Temp. (°F)	S-1*	S-2**	NS***	Difference: Humidity Sub Group	Temp. (°F)	S-1*	S-2**	NS***
0%	0 to 40	1.3	2.8	1.3	0%	0 to 40	2.7	3.5	2.7
	100	-	-	-		100	-	-	-
75%	0 to 40	2.5	1.7	2.3	75%	0 to 40	2.7	2.1	2.1
	100	-	-	-		100	-	-	-

Gaseous Oxygen

Preference: Gaseous Oxygen Sub Group	Temp. (°F)	S-1*	S-2**	NS***	Difference: Gaseous Oxygen Sub Group	Temp. (°F)	S-1*	S-2**	NS***
Purged with N_2 twice	0 to 40	1.8	1.3	2.1	Purged with N_2 twice	0 to 40	2.1	2.5	3.0
	100	2.8	2.7	2.1		100	2.8	2.7	2.0
Purged with N_2 once	0 to 40	1.5	1.8	1.8	Purged with N_2 once	0 to 40	2.3	2.0	2.0
	100	1.8	1.8	2.1		100	1.8	2.3	2.3
Air	0 to 40	2.3	2.3	2.0	Air	0 to 40	2.5	2.7	1.3
	100	1.8	2.0	1.7		100	2.3	2.7	2.7

* Sample with the laminating mechanism
** " " " compression orientation mechanism
*** " without the softening mechanism

TABLE 83

STATISTICAL ANALYSIS OF TASTE PANEL DATA

F/D CARROT BARS STORED AT 100°F AND

0 TO 40°F (CYCLING) FOR 3 MONTHS

Preference / **Difference**

Pressure

Preference:

Source of Variation	d/f	MS
Samples	2	0.4306
Interaction	6	1.1342
Residual	60	0.5056
Error	3	1.9259
Total	71	-

Difference:

Source of Variation	d/f	MS
Samples	2	1.0556
Interaction	6	1.1296
Residual	60	1.5111
Error	3	0.9630
Total	71	-

Humidity

Preference:

Source of Variation	d/f	MS
Samples	2	0.5833
Interaction	2	5.0889 *
Residual	30	0.4889
Error	1	1.0000
Total	35	-

Difference:

Source of Variation	d/f	MS
Samples	2	0.5278
Interaction	2	1.2500
Residual	30	0.7056
Error	1	3.5833
Total	35	-

Gaseous Oxygen

Preference:

Source of Variation	d/f	MS
Samples	2	0.1204
Interaction	10	0.6870
Residual	90	0.4111
Error	5	1.5704
Total	107	-

Difference:

Source of Variation	d/f	MS
Samples	2	0.6944
Interaction	10	1.3056
Residual	90	0.9889
Error	5	0.9111
Total	107	-

* Significant at 5% level.

TABLE 84

MOISTURE CONTENTS OF SOFTENED F/D CARROT BARS STORED 3 MONTHS AT 0% AND 75%

a. Laminated Bars*

0% RH		75% RH	
0 to 40°F	100°F	0 to 40°F	100°F
3.01	0.92	24.52	19.45

b. Compression Orientated Bars*

0% RH		75% RH	
0 to 40°F	100°F	0 to 40°F	100°F
2.70	1.67	21.71	30.35

* Moisture content at 0-months storage - 6.60

TABLE 85

MICROBIOLOGICAL DATA (STANDARD PLATE COUNT PER GRAM) FOR LAMINATED FREEZE DRIED CARROT BARS STORED FOR THREE MONTHS

Pressure Sub Groups	0 to 40°F (Cycling)	100°F
Pressure Exerted on Side	4600	<3000
Pressure Exerted on Face	46000	113000
Humidity Sub Groups		
0%	<3000	<3000
75%	<3000	<3000
Gaseous Oxygen Sub Groups		
Purged with N_2 twice	4700	<3000
Purged with N_2 once	9700	6600
Air	5600	<3000

TABLE 86

MICROBIOLOGICAL DATE (STANDARD PLATE COUNT PER GRAM) FOR COMPRESSION ORIENTATED FREEZE DRIED CARROT BARS STORED FOR THREE MONTHS

Pressure Sub Groups	0 to 40°F (Cycling)	100°F
Pressure Exerted on Side	5400	<3000
Pressure Exerted on Face	5400	<3000
Humidity Sub Groups		
0%	4700	<3000
75%	5500	<3000
Gaseous Oxygen Sub Groups		
Purged with N_2 twice	5200	< 3000
Purged with N_2 once	7100	< 3000
Air	7000	< 3000

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13. ABSTRACT

Compressed bars representing various vegetables and fruits, a cereal, a bakery item, meat, a casserole type item, non fat milk solids, and a high cook caramel candy were prepared in a manner to accentuate hardness. The effectiveness of various mechanisms for improving bitability and mastication were examined. A laminating technique resulting in a bar of thin layers held together with a mild binder was observed to be generally applicable, since individual layers could be separated for easy mastication and accelerated hydration. For fibrous products bitability was markedly improved by application of the compressive force at 90° from the direction of the bite. Physical, chemical and sensory data are recorded for bars stored at four different temperatures.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Development	8					
Testing	8					
Lamination	9		6			
Mechanism	9		6			
Food bars	9		9			
Compressed foods	9		9			
Dehydrated foods	9		9			
Freeze-dried foods	9		9			
Military rations	4					
Softening			7			
Rehydration			7			
Flavor			7			
Acceptability			7			